MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

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REPORTS OF THE PROCEEDINGS

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OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. NOVEMBER 10, 1882. No. 1.

E. J. STONE, M.A., F.R.S., President, in the Chair.

Prof. H. G. van de Sande Bakhuyzen, The Observatory, Leyden;
Dr. W. Döllen, The Observatory, Pulkowa;
Dr. W. Klinkerfues, The Observatory, Göttingen;
Prof. H. Schultz, The Observatory, Upsala; and
Prof. H. C. Vogel, The Observatory, Potsdam,

were balloted for, and duly elected Associates of the Society.

Robert Bryant, 11, King Street, Tower Hill, E.C.;
Captain Arthur Lister Kaye, Manor House, Stretton-on-Dunsmore, Rugby; and
Jonadab Finch, Cheltenham,

were balloted for, and duly elected Fellows of the Society.

On certain Deviations from the Law of Apertures in Relation to Stellar Photometry; and on the Applicability of a Glass Wedge to the Determination of the Magnitudes of Coloured Stars. By Professor C. Pritchard, F.R.S.

I believe the Society is aware that for some time past I have been engaged in the photometric examination of the relative brightness of the stars, by means of an instrument which, though not new in its several component parts, claims to be entirely new in their combination and mode of application. The first section of the work is now all but completed, viz. that which includes the relative brightness of all the stars from the Pole to the Equator,

which, in the catalogue of Heis, are estimated as brighter than the fifth order of brightness; together with a few other stars, possessing features of interest.

In the course of this research, some facts of considerable importance, and, as I think, possessing some novelty, having presented themselves, I take this opportunity of communicating them to the Society.

At an early stage of the inquiry, a doubt arose in my mind as to the perfect accuracy of the law which expresses the ratio of the amount of light successively transmitted by varying the aperture of the same object-glass. In my method of stellar photometry, the accuracy of this law was assumed as exact; and, indeed, formed a most material element in the reduction of the observations. For I had determined from several hundred measures, that a certain thickness of neutral-tinted glass, indicated by a measured interval along the wedge, reduced the light of a star by the same amount as that which is extinguished by halving the aperture of the object-glass; according to the generally accepted theory, this reduction of light is in the proportion of four to one. And in this way I was led to that method of reducing the wedge observations which has been already explained to the Society in my communication of November last, just twelve months ago.

I had reason to doubt the strict accuracy of this law, both from the nature of certain resulting deductions which forced themselves on my attention, and from the consideration that the complex structure of an object-glass consists virtually of a series of reversed wedges of two different kinds of glass differing in their thickness. Moreover, I had also been somewhat startled at conclusions arrived at by Dr. Wolff, of Bonn, in his photometrical observations published at Leipzic 1877. Dr. Wolff, in this really valuable and interesting work, states that he used a Zöllner Photometer, after having submitted it to the necessary tests. Among these tests he compared the ratio of the light transmitted from the same star through telescopic apertures varying approximately in the ratio of 3, 2, 1: the ratio of the lights so transmitted would, he expected, be in the ratio of 9, 4, 1; but as exhibited by the Zöllner Photometer, these ratios came out utterly, and as it seemed hopelessly, discordant., as will be seen from the exact figures given below.* Whether the causes which led to this most unexpected and discordant result, are rightly conjectured by Dr. Wolff or not, the fact remains; and, if unexplained or disregarded would seem to suggest some preliminary doubts either as to th

* The exact diameters of the several apertures of the object-glass were respectively 37·4 mm., 25·9 mm., and 13·9 mm. From these figures Dr. Wolff calculates that the logarithmic ratio of the light of a star as seen with the two foregoing apertures of 37·4 mm. and 13·9 mm., should be 0·8766 [qu. 0·8597], whereas the ratio derived from actual observation was 0·3384. The numbers corresponding to these logarithms are respectively 7·53 [qu. 7·24] and 2·18: that is, the actual instrumental result was about 3½ times less than it should have been on the generally adopted theory of apertures!

competency of the instrument, or as to the validity of the methods employed. I was quite sure that in the case of my own inquiries no such deviation from the generally received law of apertures could possibly exist; but, nevertheless, it now was more than ever necessary to determine, for the purposes of my own research, the exact ratio of the light transmitted by varying the aperture. I had in fact assumed, as other astronomers had assumed before me, that by halving the aperture, one-fourth part of the light was transmitted.

The late Mr. Johnson also undertook a series of experiments in nearly the same direction. He found that one of the halves of the heliometer objective transmitted more light than the other half, in the ratio of 1000 to 924; and further, that probably the central parts of the objective of the Oxford Heliometer are more transparent than the parts near to the circumference. The consequences of this latter result, however, he does not pursue further; but, notwithstanding his suspicions, he assumes throughout his investigations on the magnitude of certain stars, that the strict accuracy of the commonly received law of apertures is maintained.

Under these circumstances it was necessary, for the purposes of establishing the exactness of my photometry, to institute some crucial experiments, if such could be devised.

The first process which suggested itself to my mind was to ascertain, by means of my wedge, the relative amount of light transmitted 1° by the full aperture of 4 inches; 2° by the reduced aperture of 2 inches; and 3° by the full aperture, having a circular patch of two inches in diameter in the centre. This process must lead to the solution of the question before us, as will be obvious on a consideration of the case. But, instead of having recourse to this method of investigation, which, to be efficacious, would necessarily require much time and many observations, I thought it better to adopt an independent form of photometric examination, founded on the same principles of double refraction as those which have been so successfully applied by Prof. Pickering at Harvard College, and suggested in the *Observatory* of August 1882.

The method itself appears to me to be one of great beauty, readiness, and accuracy. It consists, mainly, in comparing the amount of light transmitted at different successive points on the wedge, by means of a double-image prism of quartz and a Nicol prism. The wedge was thus examined at every tenth of an inch throughout its extent, and its general uniformity was established to a degree which I had hardly ventured to expect. The conclusion I arrived at was, that on this hypothesis of practical uniformity, measures of light carefully made with the wedge ought not to lead to an error exceeding about the thirteenth of a magnitude. The full particulars of these experiments must be reserved until the publication of the complete memoir on the photometry of the brighter stars of the northern hemisphere is

communicated to the Society. For the present, the following results, and explanation of the method employed, may be interesting and sufficient. An opaque moveable screen was placed over the wedge, and in this screen two rectangular apertures were cut, whose centres were distant from each other by 0·3741 inches; the breadth of each of the apertures was 0·022 inches. Parallel light was then transmitted through the wedge at these two apertures, either from the Sun or from a gas lamp (and in a subsequent series of experiments through coloured glasses or coloured liquids); the ratio of the emergent lights through these two apertures was then measured by the double-image photometer, and the results are given in column 2 of the following table.

Wedge A, for use with a 4-inch Telescope.

Successive Positions of Screen. inches.	Mean Light Ratio.	Error of the Mean.	Equivalent Magnitude. (Pogson's scale.)	Error of the Mean in Magnitude.
From 0·3 to 0·9	1·919	0·026	0·71	0·015
1·0 „ 1·9	1·885	0·037	0·69	0·022
2·0 „ 2·9	1·901	0·031	0·70	0·019
3·0 „ 3·9	1·903	0·028	0·70	0·017
4·0 „ 4·9	1·889	0·027	0·69	0·017
5·0 „ 5·9	1·877	0·031	0·68	0·017

Wedge B, for use with a 3-inch Telescope.

From 0·5 to 1·4	2·443	0·029	0·970	0·012
1·5 „ 2·4	2·448	0·040	0·972	0·018
2·5 „ 3·5	2·445	0·036	0·971	0·016

Column 1. These figures mean (taking the first line as an example) that the wedge was photometrically tested at every tenth of an inch throughout the interval of wedge beginning at 0·3 in. from the end and ending at 0·9 in. towards the thicker part. Column 2 gives the mean of the ratio of the light transmitted at each successive tenth of an inch; as, for example, when the screen was moved from 0·3 in. to 0·4 in., to 0·5 in., up to 0·9 in. Column 4 is column 2 expressed in magnitude, assuming the light ratio for a single magnitude to be 2·512. Columns 3 and 5 explain themselves.

A further discussion of the results thus obtained leads also to the ratio of the light transmitted by the two telescopes employed when their linear apertures were halved. This ratio in the case of the 4-inch telescope is 3·918 : 1. In the 3-inch telescope this ratio is 3·921 : 1. These ratios approximate to the ratio of 4 : 1 hitherto I believe universally adopted; but, nevertheless, the error which would be thus introduced in the photometric reduction is by no means inconsiderable. For example, in the comparison of two stars differing by only three orders of brightness, the error thus

introduced would amount to nearly a tenth of a magnitude, an amount of error which is not admissible in the accurate photometry aimed at, and shown to be attainable by my method. Indeed, this deviation from exactness was sufficient to compel me to modify the reduction of the observations of several hundreds of stars. Moreover, it is of the nature of a systematic error, and would probably become greatly increased and very serious, if the aperture of the telescope were still further reduced to those much smaller dimensions (one-seventh of an inch for example) which have been recommended by preceding astronomers. Further, these investigations seem to suggest that it would be impossible to apply any method of telescopic apertures alone, to the photometry of the stars, unless the idiosyncracies of the particular object-glass employed were accurately ascertained by some independent method of photometry.

While I was engaged in the foregoing inquiry into the capacity of the wedge as regards the amount and uniformity of its absorption of ordinary light, I availed myself of the opportunity of examining its effects on lights of different colours; and this I did with the expectation of ascertaining how far the wedge method of photometry could be relied on in the case of coloured stars, whether single or double. With this view I interposed coloured glasses and other coloured media between the source of light and the wedge, and I ascertained, as the result, that within the limits of our unavoidable errors of observation the same thickness of wedge practically absorbed the same amount of light, whether its colour be red, orange, yellow, green, or blue. I confess that I was agreeably surprised at this result, although I think that, in part at least, it might have been anticipated; because, in the process of extinguishing the light of stars through the wedge, there had been no consciousness in the mind of the observer, of different colours in the case of particular stars. If this result be confirmed, as I think it will be, by still more numerous observations, it is obvious that in the wedge we possess an instrument applicable to the photometry of coloured stars. It may here be interesting to give a few numerical results.

The mean absorptive power of the wedge B for different moderately coloured lights, obtained by the process referred to in Table I., is as follows :—

White light from Sun	2·445 = 0·97 mag.
Red light	2·432 = 0·96
Orange	2·436 = 0·97
Green	2·426 = 0·96
Blue	2·421 = 0·96

The characters of these various media were examined *spectroscopically*, with the following results. The band of absorption extended, in the case of the

Red medium; from wave-length	527 to w.l. 468,	*i.e.* E to ½ (F + G)		
Orange medium;	518 „	420 „	*b* to G	
Green medium;	691 „	590 „	B to D	
Blue medium;	760 „	653 „	A to C	

In still further confirmation of the applicability of this method of stellar photometry I may place a few observations of coloured double stars made at Oxford with the wedge now referred to, in juxtaposition with observations of the same stars made at Harvard College by Professor Pickering with his double image photometer.

Star's Name.	Colours of Components. A	B	Difference of Magnitude. Wedge (Oxford)	Double Image (Harvard)	Σ's estimation.
η Cassiopeia ...	*y*	*p*	3·77	3·85	3·6
ψ′ Piscium ...	*w*	*w*	0·22	0·20	0·3
ζ Piscium ...	*w*	*w*	0·86	0·96	1·1
γ Andromedæ .	*gl*	*b*	2·72	2·85	2·0
α Piscium ...	*g*	*b*	0·97	0·90	1·4
Castor ...	*grsh*	*grsh*	0·75	0·82	1·0
α Can. Ven. ...	*w*	*w*	2·33	2·56	2·2
ε Boötis ...	*v.y*	*v.b*	2·46	2·43	3·3
ζ Lyræ ...	*gr.w*	*gr.w*	1·11	1·38	1·1
ε Lyræ ...	*gr.w*	*bl.w*	1·01	0·96	1·7
5 Lyræ ...	*v.w*	*v.w*	0·36	0·23	0·3
θ Serpentis* ...	*y*	*y*	0·33	0·87	0·1
β Cygni ...	*y*	*b*	1·74	2·14	2·1
β Cygni (Nov. 6)			1·82		
γ Delphini ...	*gl*	*bg*	0·93	0·99	1·0

There remains another question for consideration, viz. the effect of the atmosphere on the light of the stars as seen at varying altitudes. In my first communication to the Society I cursorily touched upon this point, and I thought I had satisfied myself that, for stars observed at altitudes exceeding 50°, the difference in the amount of the atmospheric extinction of light is so small that it can be allowed for or even disregarded without appreciable error; but that at lower altitudes the effects are so variable, and seem to depend upon elements so inconstant, at all events in our climate, that very sensible errors may easily be admitted from this cause. Dr. Seidel's tables do probably represent

* Looking at Professor Pickering's individual measures, it seems probable that one of the components of this star may be variable.

average results, but do not seem to be available in individual cases. Dr. Wolff goes so far as to state that, in his particular locality, he regards even the azimuth of a star to be an element in the amount of stellar light extinguished. This may be the case at Oxford also, possibly owing to the confluence of so many streams of water. And this suspicion is by no means to be disregarded in reference to our own method of observation; because this method, in part, consists in not observing stars necessarily on the meridian, but in such positions as shall best secure a general uniformity in the altitudes of all the stars observed. Considering the difficulty and importance of this branch of the subject, and the necessity of varying both the meteorological and the geographical conditions under which the observations should be made, I purpose to undertake a journey to the south, probably to Cairo, in order to collect additional information for the solution of the problem, and to render this contribution to stellar photometry as complete as possible.

In what has been herein advanced, regarding

(1) The caution that is now shown to be necessary before adopting a method of photometry by varying telescopic apertures;
(2) The possibility of securing practical accuracy of stellar photometry in the use of a wedge of neutral-tinted glass;
(3) The possibility of correctly measuring thereby the relative brilliance of coloured stars, whether single or double,

I hope something useful has been added to our astronomical methods of research.

On Observations of Comets 1881 *II. & III., of Wells's Comet, and of the Great Comet* (b) 1882, *made at the Royal Observatory, Cape of Good Hope.* By David Gill, LL.D., Her Majesty's Astronomer at the Cape of Good Hope.

The following papers contain all the observations of comets made at this Observatory since 1880, with the exception of a few observations of Wells's Comet, made with the heliometer, and those of the present Great Comet, which are not yet reduced.

In April 1881, when on a brief visit to England, I took with me, and forwarded to Messrs. Repsold, of Hamburg, the tube of the 8½-foot equatorial, for the purpose of having a new micrometer and new illuminating arrangements made for it.

During my absence, and whilst the tube was with Messrs. Repsold, Tebbutt's Great Comet appeared, and it was admirably

observed with the heliometer, by my friend and guest Dr. Elkin. His observations of this comet form the first part of the present communication.

About the beginning of September 1881 it became desirable to secure observations of Schäberle's Comet in the southern hemisphere, and these observations were of necessity first made with the heliometer. The opportune arrival of the Repsold micrometer prevented the discontinuity of the series of observations, as the comet, at the end of September, was becoming too faint for the limited light-grasp of the heliometer. The exquisite bright wire illumination of the new Repsold micrometer, capable of the most perfect modulation, permitted observations to be made whenever the comet was visible in a dark field. The comet was followed till Oct. 18, when it only became visible in twilight a few minutes before it set behind Table Mountain. The last observations were made with the mountain's ridge in the edge of the field of view.

The observations made by myself are indicated by the letter G, those by Dr. Elkin by the letter E.

I have thought it desirable to publish Mr. Finlay's observations of Wells's Comet without waiting for meridian observations of the comparison stars. These determinations can equally well be made at some of the numerous northern observatories, and many of the stars have probably been already observed in connection with the zone observations of the *Astronomische Gesellschaft.*

The observations of the Great Comet of the present year are accompanied by notes from the different observers.

Royal Observatory,
Cape of Good Hope:
1882, *Oct.* 9.

Heliometer Observations of Comet 1881 *II.* (*Tebbutt*), *made by W. L. Elkin, Ph.D.*

1881.	Cape Mean Time.	Distance.	Obs.	Position Angle.	Obs.	Δα	Δδ
	h m s	"		° '		' "	' "
May 31	6 19 24	2057·3	4	177 27·6	4	+ 1 44·7	−34 15·2
June 1	6 8 51	1578·3	2				
3	5 53 47	3561·8	4	96 40·7	4	+65 48·6	− 6 54·2
3	6 27 4	1495·2	2	215 1·9	2	−15 56·8	−20 24·4
4	5 59 57	3544·0	4	354 2·0	4	− 6 48·4	+58 44·7
8	5 48 9	4586·6	2				
9	5 31 18	2514·8	4	30 58·3	4	+22 26·6	+35 56·3
9	18 3 8	1393·6	4	38 15·9	4	+14 51·8	+18 14·2

1881.	Mean Places of Comparison Stars.		Authority.	Red. to App. Place.	
	° ′ ″	° ′ ″		″	″
May 31	75 44 41·7	−29 1 59·8	2 Merid. Obs.	+2·5	−1·5
June 1	75 44 41·7	−29 7 59·8	„	+2·6	−1·3
3	75 6 34·0	−26 18 49·6	Stone	+4·3	−0·3
3	76 28 35·0	−26 3 35·6	Stone	+4·4	−0·9
4	76 28 35·0	−26 3 35·6	Stone	+4·5	−0·7
8	78 23 13·9	−18 15 28·1	3 Merid. Obs.	+8·7	−0·7
9	76 53 47·3	−16 20 50·6	Stone	+9·6	0·0
9	77 8 43·6	−14 44 46·8	3 Merid. Obs.	+10·3	0·0

Apparent Places of Comet.

May 31	75° 46′ 28″·9 +	[9·980]p	−29° 42′ 16″·5 +	[9·673$_n$]p
June 1		[9·973]		[9·665$_n$]
3	76 12 26·9	[9·965]	−26 25 44·1	[9·665$_n$]
3	76 12 42·6	[9·967]	−26 24 0·9	[9·711$_n$]
4	76 21 51·1	[9·962]	−25 4 51·6	[9·684$_n$]
8		[9·943]		[9·711$_n$]
9	77 16 23·5	[9·934]	−15 44 54·3	[9·727$_n$]
9	77 23 45·7	[9·931$_n$]	−14 26 32·6	[9·725$_n$]

p being the horizontal parallax, expressed in seconds of arc, and the numbers in brackets logarithms.

Heliometer Measures of Comet 1881 *III.* (*Schäberle*).

1881.	Obs.	Star of Comp.	Distance.	No. of Bisec.	Position Angle.	No. of Bisec.	Δα	Δδ
			″		° ′		m s	′ ″
Aug. 31	E	α	173·4	4	192 30·8	4	−0 2·58	− 2 49·2
31	G	α	207·1	4	182 43·3	4	−0 0·68	− 3 26·8
Sept. 1	E	β	3352·4	4	280 8·4	4	−3 44·45	+ 9 50·2
1	G	β	3275·6	4	278 16·3	4	−3 40·46	+ 7 51·2
3	G	γ	1613·2	4	289 21·6	4	−1 42·06	+ 8 54·8
3	E	γ	1552·7	4	287 30·8	4	−1 39·29	+ 7 47·2
6	E	ε	4091·3	4	275 19·6	4	−4 31·58	+ 6 19·8
6	E	δ	5027·4	4	228 16·6	4	−4 10·16	−55 45·9
7	E	ζ	3070·4	4	260 32·5	4	−3 22·06	− 8 24·6
7	G	ζ	3042·4	4	259 7·7	4	−3 19·34	− 9 33·8
8	G	η	2972·0	4	77 27·7	4	+3 13·90	+10 45·2
8	E	η	2991·3	4	78 43·7	4	+3 16·08	+ 9 44·7
9	E	θ	926·8	4	164 32·4	4	+0 16·58	−14 53·3
9	G	θ	993·9	4	163 32·0	4	+0 18·87	−15 53·2

1881.	Obs.	Star of Comp.	Distance.	No. of Bisec.	Position Angle.	No. of Bisec.	Δα	Δδ
			″		° ′		m s	′ ″
Sept. 12	G	ι	1265·0	4	80 7·6	4	+1 24·31	+ 3 36·9
12	E	ι	1279·5	4	81 59·3	4	+1 25·72	+ 2 58·3
14	G	κ	2671·5	4	355 9·2	4	−0 15·41	+44 21·9
14	E	κ	2628·4	4	355 27·7	4	−0 14·20	+43 40·2
15	E	λ	1910·3	4	126 52·1	4	+1 44·63	−19 6·2
15	G	λ	1941·4	4	127 27·3	4	+1 45·51	−19 40·6
19	G	μ	2414·7	4	128 11·4	4	+2 11·96	−24 53·0
19	E	μ	2450·9	4	128 34·3	4	+2 13·24	−25 28·1
21	G	ν	2303·6	4	264 25·2	4	−2 40·89	− 3 44·0
21	E	ν	2297·8	4	263 35·0	4	−2 40·24	− 4 16·8
23	G	ξ	611·3	4	160 57·1	4	+0 14·11	− 9 37·8
23	E	ξ	641·1	4	161 1·0	4	+0 14·75	−10 6·2
24	G	ο	3329·5	4	301 50·3	4	−3 21·22	+29 16·4
24	E	ο	3305·7	4	301 24·9	4	−3 20·74	+28 43·0
27	E	π	364·7	4	277 17·7	4	−0 25·99	+ 0 46·3
27	G	π	356·2	4	272 42·1	4	−0 25·56	+ 0 16·7

Apparent Places of Comet 1881 III. (Schäberle), deduced from Heliometer Measures.

1881.	Cape Mean Time.	α		δ	
	h m s	h m s		° ′ ″	
Aug. 31	7 9 56	13 22 35·89	+[8·720]p	+14 21 56·3	+[9·792$_n$]p
31	7 15 17	13 22 37·79	[8·724]	+14 21 18·7	[9·787$_n$]
Sept. 1	6 39 23	13 30 0·15	[8·682]	+11 30 48·2	[9·800$_n$]
1	6 53 39	13 30 4·14	[8·697]	+11 28 49·2	[9·795$_n$]
3	6 30 4	13 42 46·32	[8·658]	+ 6 14 5·6	[9·780$_n$]
3	6 41 15	13 42 49·09	[8·671]	+ 6 12 58·0	[9·779$_n$]
6	6 40 38	13 57 31·46	[8·664]	− 0 22 40·6	[9·741$_n$]
6	7 11 51	13 57 36·98	[8·698]	− 0 25 14·6	[9·743$_n$]
7	6 38 14	14 1 29·72	[8·661]	− 2 15 18·5	[9·727$_n$]
7	6 55 0	14 1 32·44	[8·681]	− 2 16 27·7	[9·731$_n$]
8	6 46 34	14 5 7·65	[8·674]	− 4 0 8·0	[9·719$_n$]
8	7 1 42	14 5 9·83	[8·690]	− 4 1 8·5	[9·721$_n$]
9	7 17 4	14 8 28·41	[8·706]	− 5 38 37·4	[9·715$_n$]
9	7 24 58	14 8 30·70	[8·720]	− 5 39 37·3	[9·721$_n$]
12	6 43 17	14 16 38·04	[8·679]	− 9 46 2·4	[9·674$_n$]
12	6 56 59	14 16 39·45	[8·695]	− 9 46 41·0	[9·681$_n$]
14	6 49 24	14 21 5·36	[8·694]	−12 5 12·6	[9·660$_n$]
14	7 4 18	14 [illegible]	[illegible]	−12 5 56·3	[9·670$_n$]

1881.	Cape Mean Time. h m s	α h m s		δ ° ′ ″	
Sept. 15	7 5 54	14 23 5·40	[8·715]p	−13 8 40·7	[9·664$_n$]p
15	7 20 50	14 23 6·28	[8·727]	−13 9 15·1	[9·675$_n$]
19	6 53 57	14 29 43·63	[8·718]	−16 42 45·7	[9·634$_n$]
19	7 9 31	14 29 44·91	[8·730]	−16 43 20·8	[9·647$_n$]
21	7 18 49	14 32 30·93	[8·746]	−18 13 27·0	[9·654$_n$]
21	7 35 43	14 32 31·58	[8·754]	−18 13 59·8	[9·672$_n$]
23	7 51 16	14 35 0·40	[8·765]	−19 34 45·8	[9·684$_n$]
23	8 4 52	14 35 1·04	[8·768]	−19 35 14·2	[9·698$_n$]
24	7 10 55	14 36 7·41	[8·750]	−20 11 7·2	[9·636$_n$]
24	7 26 21	14 36 7·89	[8·759]	−20 11 40·6	[9·655$_n$]
27	7 16 4	14 39 17·81	[8·763]	−21 53 27·6	[9·642$_n$]
27	7 38 33	14 39 18·24	[8·771]	−21 53 57·2	[9·672$_n$]

p being the horizontal parallax of the comet, expressed in seconds of arc, and the numbers in brackets logarithms.

Measures of Δα and Δδ of Comet III. (Schäberle), from Comparison Stars, with the 8½ ft. Equatorial.

1881. d	Cape Mean Time. h m s	Obs.	Star.	Δα m s	Cape Mean Time. h m s	Δδ ′ ″
Sept. 30	7 18 13	G	*a*	−2 18·56 (6)	7 12 3	− 0 56·4 (3)
Oct. 1	7 10 9	E	*b*	−0 6·68 (12)	7 9 48	− 7 2·7 (6)
2	7 14 45	E	*c*	−0 31·00 (6)	7 19 10	+ 4 7·5 (1)
3	7 17 49	E	*d*	−1 3·21 (4)	7 18 44	+14 50·7 (5)
4	7 11 51	E	*d*	−0 14·63 (6)	7 19 57	−10 11·1 (5)
7	7 12 14	E	*e*	+0 51·36 (8)	7 25 33	− 2 52·8 (5)
10	7 22 44	G	*f*	+0 13·21 (8)	7 23 22	− 2 2·1 (4)
11	7 19 41	E	*g*	+0 22·01 (12)	7 20 12	− 6 45·3 (6)
12	7 27 40	E	*h*	+0 17·08 (9)	7 21 41	− 2 22·5 (4)
14	7 31 7	G	*i*	+2 47·98 (10)	7 35 9	+ 1 36·1 (6)
16	7 24 59	G	*l*	+0 17·50 (3)	7 19 2	− 5 58·7 (2)
17	7 30 47	G	*m*	−2 18·18 (10)	7 22 30	− 2 44·5 (4)
18	7 32 3	G	*n*	+3 3·17 (3)	7 27 21	+ 6 49·5 (1)
18	7 32 3	G	*o*	+2 56·60 (3)	7 27 21	+ 3 14·1 (1)

Notes.—Oct. 2. Comet faint, through fog, for pointing in declination uncertain.

16. Comet only barely visible.

Apparent Places of Comet 1881 III. (Schäberle), from Observations with the 8½-ft. Equatorial.

Cape Mean Time.		α		Cape Mean Time.	δ	
1881.	h m s	h m s		h m s	° ′ ″	
Sept. 30	7 18 13	14 42 6·94	+[8·772]p	7 12 3	−23 23 3·5	+[9·639$_n$]p
Oct. 1	7 10 9	14 42 59·10	[8·771]	7 9 48	23 50 41·0	[9·637$_n$]
2	7 14 45	14 43 51·57	[8·776]	7 19 10	24 17 32·6	[9·652$_n$]
3	7 17 49	14 44 42·07	[8·779]	7 18 44	24 42 59·1	[9·654$_n$]
4	7 11 51	14 45 30·66	[8·780]	7 19 57	25 8 0·9	[9·659$_n$]
7	7 12 14	14 47 52·58	[8·787]	7 25 33	26 17 44·1	[9·674$_n$]
10	7 22 44	14 50 6·78	[8·794]	7 23 22	27 21 24·8	[9·680$_n$]
11	7 19 41	14 50 49·94	[8·796]	7 20 12	27 41 27·0	[9·678$_n$]
12	7 27 40	14 51 33·94	[8·797]	7 21 41	28 1 11·5	[9·684$_n$]
14	7 31 7	14 52 58·31	[8·799]	7 35 9	28 39 5·5	[9·662$_n$]
16	7 24 59	14 54 21·04	[8·801]	7 19 2	29 15 27·5	[9·675$_n$]
17	7 30 47	14 55 2·46	[8·802]	7 22 30	29 32 42·6	[9·662$_n$]
18	7 32 3	14 55 42·53	[8·802]	7 27 21	29 49 52·2	[9·660$_n$]
18	7 32 3	14 55 42·51	[8·802]	7 27 21	29 49 52·2	[9·660$_n$]

p being the horizontal parallax of the comet in seconds of arc, and the numbers in brackets logarithms.

Mean Right Ascensions and Declinations of Comparison Stars for Comet 1881 III. (Schäberle), from Observations with the Transit Circle at the Royal Observatory, Cape of Good Hope, in the year 1882.

Heliometer Stars.	α 1882·0	δ 1882·0	*Equatorial Stars.*	α 1882·0	δ 1882·0
	h m s	° ′ ″		h m s	° ′ ″
α	13 22 39·40 (3)	+14 24 34·42 (3)	b	14 43 6·65 (3)	−23 43 42·08 (4)
β	13 33 45·48 (3)	+11 20 47·31 (3)	a	14 44 26·36 (3)	−23 22 10·86 (3)
γ	13 44 29·21 (3)	+ 6 5 1·18 (3)	c	14 44 23·44 (3)	−24 21 43·91 (3)
δ	14 1 47·90 (3)	+ 0 30 22·73 (3)	d	14 45 46·18 (3)	−24 57 53·51 (3)
η	14 1 54·53 (3)	− 4 11 0·64 (3)	e	14 47 2·13 (3)	−26 14 55·02 (3)
ϵ	14 2 3·81 (3)	− 0 29 8·72 (3)	i	14 50 11·28 (3)	−28 40 45·48 (3)
ζ	14 4 52·53 (3)	− 2 7 1·81 (3)	f	14 49 54·50 (3)	−27 19 26·67 (3)
θ	14 8 12·60 (3)	− 5 23 51·29 (3)	g	14 50 28·86 (3)	−27 34 45·45 (3)
ι	14 15 14·50 (3)	− 9 49 45·45 (3)	h	14 51 17·78 (3)	−27 58 52·80 (4)
κ } λ }	14 21 21·54 (3)	−12 49 39·98 (3)	n	14 52 40·32 (3)	−29 56 45·73 (3)
μ	14 27 32·47 (3)	−16 17 57·53 (3)	o	14 52 46·87 (3)	−29 53 10·30 (3)
ξ	14 34 47·11 (3)	−19 25 13·28 (3)	l	14 54 4·49 (3)	−29 9 32·78 (3)
ν	14 35 12·61 (3)	−18 9 47·48 (3)	m	14 57 21·59 (3)	−29 30 1·99 (3)
o	14 39 29·45 (3)	−20 40 27·59 (3)			
π	14 39 44·14 (3)	−21 54 17·87 (3)			

The figures in brackets denote the number of days on which each star was observed on the meridian.

Comet 1882 (*Wells*).

The observations of this comet were made by Mr. W. H. Finlay, first assistant, with the 7-inch equatorial.

The comet was first found at the Cape on June 14, by the help of an ephemeris computed by Messrs. Finlay and Elkin, from Dr. Bigourdan's elements. On that date one transit of the comet and of γ *Geminorum* was taken across the ring micrometer. Unfortunately the changes of the refractions at the low altitude caused the star to pass nearly across the middle of the ring, so that the difference of declination is of very little value. This observation gives

$$\text{June } 14^{d}\ 5^{h}\ 47^{m}\ 44^{s}.4 \text{ C.M.T.} \qquad \alpha = 6^{h}\ 14^{m}\ 30^{s}.29 + 0.0560p$$

$$\delta = +16'\ 23''.5\ - 0.589\ p$$

where p denotes the comet's horizontal parallax in seconds of arc.

When first seen on June 14, the comet had a large diffused head without any marked condensation, and a tail about 2° long in the twilight. The centre of this diffused head was observed throughout, but on two occasions, when the definition was better than usual, a bright stellar nucleus was seen in the preceding part of the head.

On June 17 the tail was considerably curved towards the south, and the northern side and edge were much brighter and better defined than the southern.

After July 24 the entries were made by Dr. Elkin at a given signal, on account of the faintness of the comet.

Moonlight prevented observations after August 16.

Date.	Cape Mean Time.	d' (R.A.) $\delta - *$	No. of Comparison.	Parallax in R.A.	d (Decl.) $\delta - *$	No. of Comparison.	Parallax in Decl.	Comparison Star.
	h m s	m s			′ ″			
1882, June 17	5 47 25·4	+4 13·05	10	+·0532p				Arg. +15°, 1431
	5 46 14·4				+6 20·00	2	−·618p	„
	6 2 50·8	−4 37·96	1	+·0546p				Arg. +15°, 1494
	6 14 35·7				+5 2·13	1	−·595p	„
	6 11 3·5				−0 30·74	1	−·591p	Arg. +15°, 1482
18	5 51 10·3	+0 24·86	23	+·0525p				Arg. +15°, 1541
	6 1 43·2				2 21·73	16	−·615p	„
19	6 6 56·4	+0 23·51	10	+·0531p				Arg. +15°, 1601
	6 6 42·2				+5 35·41	8	−·627p	„
20	6 16 19·2				−1 38·84	6	−·617p	Arg. +15°, 1673
	6 23 47·4	−2 35·69	20	+·0537p				„
21	6 17 33·1				+2 38·29	5	−·623p	Arg. +14°, 1806
	6 20 32·5	−1 25·08	14	+·0525p				„
23	6 10 38·7	+0 37·75	12	+·0496p				Arg. +14°, 1882
	6 30 6·0				+3 26·19	6	−·624p	„
24	6 2 57·1	+0 58·91	28	+·0476p				Arg. +14°, 1917
	6 4 20·0				+1 22·45	10	−·649p	„
25	6 13 26·4				+0 24·55	12	−·645p	Arg. +13°, 1981
	6 18 22·3	−0 38·61	32	+·0487p				„

Date.	Cape Mean Time.	a' (R.A.) ♂ − ✱	No. of Comparison.	Parallax in R.A.	d (Decl.) ♂ − ✱	No. of Comparison.	Parallax in Decl.	Comparison Star.
	h m s	m s			′ ″			
1882, June 26	6 30 48·1	−3 20·47	25	+·0494p				Arg. + 13°, 2019
	6 30 0·7				−0 14·25	4	−·637p	„
	6 9 27·2	−0 5·65	4	+·0465p				✱ a
	6 15 15·7				+0 43·37	4	−·647p	„
29	6 33 41·1	+2 32·86	30	+·0475p				Arg. + 12°, 2021
	6 31 25·4				+6 35·76	6	−·642p	„
30	6 18 24·0	+0 46·59	24	+·0446p				Arg. + 12°, 2049
	6 23 0·1				−5 37·08	4	−·649p	„
	6 33 43·3	−0 42·14	28	+·0468p				Arg. + 12°, 2053
	6 41 50·0				+1 25·64	10	−·637p	„
July 1	6 18 30·9	−1 15·62	32	+·0439p				Arg. + 12°, 2076
	6 24 35·0				−6 9·58	6	−·648p	„
2	6 38 43·1	−2 8·60	4	+·0462p				Arg. + 11°, 2108
	6 46 3·0				+2 59·98	3	−·636p	„
8	6 54 28·2	−1 49·49	28	+·0461p				Arg. + 10°, 2157
	6 55 54·4				−5 26·78	8	−·629p	„
9	6 37 55·4				+5 17·53	10	−·637p	ρ Leonis
	6 38 13·0	+0 10·59	31	+·0434p				„
10	6 43 52·2				+3 15·96	4	−·633p	Arg. + 9°, 2384
	6 43 42·7	−2 24·92	20	+·0440p				„

Date.	Cape Mean Time.	d (R.A.) $\delta - *$	No. of Comparison.	Parallax in R.A.	d (Decl.) $\delta - *$	No. of Comparison.	Parallax in Decl.	Comparison Star.
	h m s	m s			′ ″			°
1882, July 11	6 37 11·7				+2 8·92	12	−·635p	Arg. + 3°, 9295
	6 37 34·2	+0 18·28	20	+·0428p				„
12	6 43 58·9				−3 31·69	4	−·619p	*b
	6 44 55·2	+1 19·19	12	+·0467p				
	7 9 0·5				+6 20·33	6	−·630p	Arg. + 9°, 2409
	7 5 3·6	+0 12·04	10	+·0437p				„
13	6 32 43·5				+0 59·53	10	−·634p	Arg. + 8°, 2423
	6 33 9·7	+0 22·15	20	+·0417p				„
14	6 59 34·0				−2 13·02	8	−·621p	Arg. + 8°, 2437
	7 0 53·2	−0 3·63	11	+·0458p				„
15	6 46 45·0				−3 28·34	6	−·625p	Arg. + 8°, 2454
	6 49 46·2	−2 43·37	15	+·0442p				„
19	7 16 19·9				−5 5·19	6	−·607p	Arg. + 7°, 2434
	7 14 6·3	+0 16·72	5	+·0474p				„
20	7 10 57·9				+3 29·96	8	−·608p	Arg. + 7°, 2440
	7 11 11·5	+0 4·91	10	+·0470p				„
21	6 55 36·2				−0 32·70	8	−·612p	*c
	6 55 58·6	−0 44·39	15	+·0449p				„
22	6 37 30·8	−0 14·94	5	+·0422p				Arg. + 7°, 2451
	6 43 55·7				+0 47·33	2	−·615p	„

Date.	Cape Mean Time. h m s	d (R.A.) ♂ − ✱ m s	No. of Comparison.	Parallax in R.A.	d (Decl.) ♂ − ✱ ′ ″	No. of Comparison.	Parallax in Decl.	Comparison Star.
1882, July 23	7 10 7·6				+0 25·76	4	−·604p	Arg. + 6°, 2445
	7 10 11·0	+2 40·75	2	+·0470p				"
24	7 22 41·4	+1 4·93	20	+·0486p				Arg. + 6°, 2465
	7 26 14·0				−0 39·78	6	−·597p	"
26	7 12 54·6				+2 44·44	8	−·599p	Arg. + 6°, 2485
	7 12 36·3	−1 6·59	15	+·0476p				"
27	7 19 4·3				−3 44·81	4	−·595p	Arg. + 6°, 2490
	7 23 27·0	+0 1·65	6	+·0490p				"
Aug. 1	6 50 51·9				−2 8·74	8	−·596p	Arg. + 5°, 2562
	6 50 35·5	−0 17·65	20	+·0455p				"
2	7 36 19·9				+1 50·02	8	−·580p	Arg. + 5°, 2563
	7 35 22·7	+2 9·63	20	+·0511p				"
3	6 56 50·3				−0 1·68	4	−·591p	Arg. + 5°, 2573
	7 5 24·6	+0 41·00	16	+·0480p				"
4	6 40 41·2				−1 45·62	8	−·594p	Arg. + 4°, 2572
	6 39 43·1	−0 10·60	16	+·0448p				"
8	6 58 49·3				+4 8·84	8	−·584p	Arg. + 4°, 2585
	6 56 17·1	+2 17·75	15	+·0476p				"

Date.	Cape Mean Time.	d' (R.A.) $\delta-*$	No. of Comparison.	Parallax in R.A.	d (Decl.) $\delta-*$	No. of Comparison.	Parallax in Decl.	Comparison Star.
	h m s	m s			′ ″			
1882, Aug. 11	7 29 25·1				−0 55·62	4	−·574p	Arg. + 3°, 2632
	7 42 48·2	+1 6·46	12	+·0529p				"
12	7 12 31·0				+3 30·91	8	−·576p	Arg. + 3°, 2638
	7 12 17·5	−0 7·26	8	+·0502p				"
14	6 26 25·3				−1 46·63	4	−·577p	Arg. + 3°, 2645
	7 8 24·8	+0 28·00	13	+·0502p				"
16	7 1 45·1				−1 51·19	4	. ·573p	Arg. + 3°, 2663
	7 18 29·3	−1 29·96	20	+·0516p				"

Approximate places of the stars *a*, *b* and *c* are

	Mag.	α	δ
		h m s	° ′
* *a*	10·5	8 49 15	+13 25·0
* *b*	10	10 40 57	+ 9 7·6
* *c*	10	Arg. + 7·2443 + 2ᵐ 34ˢ·6	Arg. + 7·2443 −4′ 51″

Notes.

July 14. Comet faint through cloud.

24. From 7^h 15^m to 7^h 18^m C.M.T., the comet was passing a star of about 10·5 mag. For some time it was almost impossible to separate them, but the comet seemed to pass to the south of the star.

Aug. 8, 14. Comet extremely faint.

4, 8, 16. The declinations given by Argelander for these stars seem to be 1′ too large.

Meridian Observations of the Great Comet (b) 1882 *with the Transit Circle of the Royal Observatory, Cape of Good Hope.*

	App. R.A.	App. Decl.	Observer.
	h m s	° ′ ″	
Sept. 17	11 31 49·06	+1 37 25·3	Gill
18	11 22 33·76	+0 28 50·3	„
22	11 1 59·00	−2 30 5·7	„

Heliometer Observation of Great Comet (b) 1882.

	Cape Mean Time.	App. R.A.	App. Decl.	Observer.
	h m s	° ′ ″	° ′ ″	
Sept. 8	17 13 58	144 59 52·1	−0 56 30·1	Elkin

Notes on the Great Comet (b) 1882. By David Gill, LL.D., Her Majesty's Astronomer at the Cape of Good Hope.

The comet was first seen by Mr. Finlay, chief assistant, on Sept. 7, about 17^h, when on the way to his house, after observing an occultation of 5 *Cancri*.

It was then a conspicuous object, the nucleus appearing to the naked eye as bright as a star of the third magnitude. Returning at once to the equatorial, Mr. Finlay secured comparisons with an 8th magnitude star, but from an error in reading off the Declination circle the comparison star was not at first properly identified, and hence the erroneous motion in declination which I telegraphed to the Astronomer Royal.

The following morning an excellent series of measures of position angle and distance from ι *Hydræ* were secured by Dr. Elkin with the heliometer; and Mr. Finlay, with the equatorial, obtained comparisons with an 8th mag. star. My own hands were closely tied in the evening with heliometer measures for stellar parallax [it was then the epoch of maximum parallax for α *Centauri* with my comparison stars] and with measures of *Victoria* and *Sappho* extending far into the early morning. Notwithstanding these engagements, after two hours' sleep I made an attempt on Sept. 9 to secure heliometer observations, but was only able to get a rough place from the circle readings whilst the comet was visible for a few minutes between clouds. A period of cloudy and rainy weather now set in, during which the comet could only be occasionally seen before sunrise by glimpses between clouds, and it became obvious that if observations were to be made at all, some exceptional means must be adopted to secure them—means that would enable an absolute place to be secured from a single pointing whenever opportunity offered.

Accordingly I resolved to dismount the photoheliograph, to

shift its portable observatory to a site commanding the eastern horizon, and to mount in it the great Indian theodolite.*

The work was begun on the morning of the 15th during torrents of rain, and by eleven o'clock at night the theodolite was mounted and adjusted. The following morning I was rewarded by two glimpses of the comet, and two observations of its difference in altitude and azimuth from the Sun.

The morning of Sunday, the 17th (civil reckoning), was cloudy till after sunrise, but improved in a few hours sufficiently to permit a long series of altazimuth observations to be made. In the afternoon it became evident that the comet could be followed to conjunction with the Sun's limb, and this observation was actually secured both by Mr. Finlay and Dr. Elkin.† The observation is described in the accompanying notes by the observers themselves.

The following morning, at Simon's Bay, I was astonished at the brilliancy of the comet as it rose behind the mountains on the eastern side of False Bay. There was not a cloud in the sky, only a merging into a rich yellow that fringed the blackish blue of the distant mountains, and over the mountains and amongst the yellow an ill-defined mass of golden glory rose with a beauty I cannot describe.

The Sun rose a few minutes afterwards, but to my intense surprise the comet seemed in no way dimmed in brightness, but becoming instead whiter and sharper in form as it rose above the mists of the horizon. I left Simon's Bay and hurried back to the observatory, pointing out the comet in broad daylight to the friends I met by the way. It was only necessary to shade the eye from direct sunlight with the hand at arm's-length to see the comet with its brilliant white nucleus, and dense white, sharply-bordered tail of quite $\frac{1}{2}°$ in length.

On arrival at the observatory I heard of all the wonders of the previous day, and in turn pointed out the comet, a brilliant object when viewed by shading the Sun from the eye by interposing the roof of the observatory portico.

I secured a complete meridian observation of the comet, and ten minutes afterwards the Sun's transit.

Numerous observations with the altazimuth were also secured.

* This instrument was constructed by Troughton and Simms, under the superintendence of Colonel Strange, for the great trigonometrical survey of India. It has been kindly lent to me, by General Walker, for some special researches. The telescope has $3\frac{1}{2}$ inches aperture, the horizontal circle is 3 feet in diameter, and the vertical circle 2 feet, reading by 5 and 4 microscopes respectively.

† I myself lost this unprecedented observation by a visit to Simon's Bay, for the purpose of meeting Captain Morris, R.E., as chief of the British Transit of Venus Expedition to Brisbane. Captain Morris had written by a previous mail expressing a strong wish to see me in reference to the Geodetic Survey of South Africa about to be undertaken. The prevalence of small-pox in Cape Town induced the owners of the "Liguria" (by which Captain Morris was a passenger) to order her to touch at Simon's Bay instead of Cape Town, and I was thus absent during the whole of Sunday, the 17th.

The following day (Sept. 18, astronomical reckoning), and on Sept. 22, I also obtained meridian observations. The nucleus on the 17th and 18th was as sharply defined and as easily observable as a star of the first magnitude seen by daylight, and the form of the head was also clearly visible. Drawings of the head were made the same afternoon with the 6-inch equatorial. On Sept. 22, the nucleus, as seen in the transit circle, was comparable with a star of the third magnitude seen by daylight, and the rest of the head was barely distinguishable. Cloudy weather prevailed between Sept. 18 and 22, and for some time after the 22nd, preventing my obtaining a longer meridian series.

Advantage has been taken of every available opportunity to secure extra meridian observations since the 22nd.

The results of such determinations of the place of the comet as are immediately available are given in the accompanying paper. The appearance of the comet in the early morning has been, and still continues to be, most grand and imposing.

With a direct vision prism, whose plane of dispersion was placed at right angles to the direction of the comet's tail, a complete yellow monochromatic image of the head, and of a great portion of the tail, was easily visible for a week after perihelion, but this can no longer be seen now.

The changes in the form of the nucleus are of extreme interest, as also is the formation of a delicate outer envelope, whose axis is different from that of the tail.

The description of these changes, and copies of the drawings that have been made, will form the subject of a future communication.

The Great Comet (b) 1882—*Disappearance at the Sun's Limb.* By W. H. Finlay, B.A.

On Sept. 7, at 17^h Cape mean time, I saw a comet with a large head and a tail about a degree in length. I secured a number of comparisons of the comet and Arg. $-0°$, 2229 with the 6-inch equatorial. On the 8th the brightness of both head and tail had increased very considerably. The southern edge of the tail was sharp and brighter than any other part, while the northern half seemed to stop short at some distance from the head. A nucleus was seen, situated towards the south of the centre of the head. I got several comparisons with Arg. $-0°$, 2256. Bad weather, and the want of comparison stars in the morning light, prevented my getting more observations with the 6-inch before perihelion passage.

On Sunday, Sept. 16 to 17, the comet was visible all day, and Dr. Elkin and myself made a large number of observations with the great Indian theodolite; unfortunately cloud prevented

my observing the comet on the meridian. In the afternoon I watched the comet with the 6-inch equatorial, and power 110, using a neutral-tint wedge on account of the glare of the Sun. I did not expect that the comet would reach the Sun before night, but they were rapidly approaching one another, and about 4·40 p.m. I found the Sun's limb visible at the edge of the field. The silvery light of the comet presented a striking contrast to the reddish-yellow of the Sun; the tail could only be traced to a very short distance now. After waiting some minutes I was about to observe differences of R.A., but the increasing rate at which the comet was closing up rendered it certain that it would reach the Sun in a very short time. By keeping the Sun's limb at the edge of the field I was able to follow the comet continuously right into the boiling at the limb. I lost sight of it suddenly at

$$4^h\ 50^m\ 58^s \text{ Cape M.T.,}$$

when the Sun's limb was boiling all about it. I fancied I caught a glimpse of it 3^s later, but was not sure. I then examined the Sun's disk very carefully, but could not see the slightest trace of the comet. I swept round the limb before the Sun disappeared behind the Lion Hill, but saw nothing. The sun was then very low and the definition bad.

Two measures with the micrometer about half an hour before the disappearance gave $4''$ for the diameter of the comet's disk.

Royal Observatory, Cape of Good Hope:
1882, *Oct.* 9.

Observations of the Great Comet (b) 1882. By W. L. Elkin, Ph.D.

(*Communicated by Mr. Gill.*)

My first view of the comet was on Sept. 8. It then appeared to the unassisted eye about as bright as a star of the third or fourth magnitude, with a straight tail about $2\frac{1}{2}°$ in length. The position angle of the tail, as measured at its origin with the heliometer at 4^h sidereal time, was $253°·1$. The breadth of the coma at the nucleus was estimated at $40''$ to $50''$, the nucleus itself being a nebulous mass strongly condensed in the centre, some $10''$ or $15''$ in diameter, and admitting of very accurate observation with the heliometer as such. The southern edge of the tail was sharply defined for a considerable distance, but the northern one faded away some $12'$ to $15'$ from the head. The colour of the comet's light struck me as remarkably *white*, perhaps contrasting it from recollection with comet *Wells*, which was of a brilliant golden hue.

The morning sky was always completely clouded (with the exception of some momentary breaks, Sept. 9 and 15) till

Sept. 16, when a minute or two of clear sky enabled the comet to be brought into the field of the heliometer, and throughout the day it was always a brilliant object in the telescope whenever free from clouds, and this without the slightest precautions being necessary. The forenoon was very cloudy, and only a few pointings with the great Indian theodolite were obtained; after meridian passage it was more favourable. As the comet approached the Sun in the afternoon I made unsuccessful attempts to measure its position with the heliometer from the Sun's limb; it could then only be seen with a low power (60), and disappeared on being brought up to the limb when still at some distance from this latter. Screening down the Sun with wire gauze screens was tried, but the amount of false light thereby produced rather impeded than forwarded the visibility of the comet in the Sun's vicinity; it soon, however, became apparent that the comet would be followed up close to the Sun, as seen directly through one of the half lenses, and favoured by the clouds I actually observed it to disappear among the undulations of the Sun's limb at

$$4^h\ 50^m\ 52^s \text{ Cape M.T.,}$$

the observation being considered at the time as accurate as an occultation of a star, say of the fourth magnitude, at the bright limb of the full Moon. The moment noted was when the last trace of the comet was suspected amidst the boiling of the limb: 4^s before it was still plainly visible. The undulations were, however, already some $5''$ in magnitude, and the comet was probably still some fraction of this distance from the Sun's true limb. The observation was made with one of the half lenses of the heliometer, and a piece of cardboard was placed in the focus of the telescope, covering one-half of the field, so that but a small segment of the Sun was visible, but this in the centre of the field. A red glass sunshade was used, and it appeared to me that the intrinsic brilliancy of the nucleus, and of a small portion of the emanations from it, could scarcely have been inferior to that of the Sun's surface itself.

Immediately after noting the times, I changed the low power (60) with which the previous observation was made for one of 180, and carefully scrutinised the place where the comet had disappeared, and its probable path, for about a quarter of an hour without being able to detect any traces of a body, dark or bright, on the face of the Sun. The definition was, however, with increasing zenith distance, becoming worse and worse, and I noted at the time that possibly an object of an apparent diameter of $1''$ or less might have escaped unnoticed, to which I may add that at the time of disappearance at the limb the nucleus was estimated to be still some $5''$ in diameter.

At that time it was not possible to say with any certainty whether the comet was passing behind the Sun, or between us

and the Sun, the available observations not admitting of any reliable conclusions being deduced from them. As this latter proved to have been the case, the fact of a comet's invisibility on the Sun's face, to ordinary instrumental means at least, lends an additional interest to the observation. I hope, however, in America, with a higher Sun, the rare occasion will not have been lost.

The post-perihelion development of the comet has been replete with interest, and of great grandeur, and has been followed with as much assiduity as the exceptionally unfavourable weather would permit.

Elements of the Great Comet (b) 1882. By W. H. Finlay, B.A., and W. L. Elkin, Ph.D.

T	Sept. 17·2242, G.M.T.	
ω	69° 32′ 8″	Mean Equinox 1882·0.
☊	345 59 35	
ι	141 58 59	
log q	7·888881	

These elements are founded on two meridian observations on Sept. 17, 22, and extra-meridian ones on Sept. 28, aberration and parallax being taken into account. They represent the middle place and two other observations as follows :—

	Comp. – Obs. $d\lambda$	Comp. – Obs. $d\beta$
Sept. 8	−8″	−20″
22	0	+ 5
Oct. 3	0	+24

They also give for the distance of the comet from the centre of the Sun at the moment when we saw it disappear at the limb on the afternoon of Sept. 17 :—

$$963''\cdot2,$$

which is only 5″·5 in excess of the tabular value of the Sun's semi-diameter.

The outstanding errors in the extreme latitudes are certa[illegible] greater than the uncertainties in the star places or in the obse[illegible] tions will account for, and seem to point to a slight insuffici[illegible] of the parabolic hypothesis.

It will be seen at once that the elements bear a strong [illegible] blance to those of the great comets of 1843 and 1880. [illegible] sical appearance, however, this comet differs totally from

1880, and (as far as can be gathered from the accounts) only resembles the one of 1843 in the point of extreme brilliancy at perihelion.

Royal Observatory,
Cape of Good Hope:
1882, *Oct.* 9.

The Great Comet (b) 1882. By F. C. Penrose.

I have attempted to work out the orbit of the comet graphically; and although I know I have not succeeded fully, yet I have arrived at results which, I trust, may be thought respectable. They are, at any rate, entirely independent of any published elements.

T	Sept. 17·23,
Longitude of ascending node	$348^{\circ}\ 20'$,
Inclination	$37\ \ 15$,

the orbit being an ellipse with a period of about 480 days. The above elements were got from observations subsequent to perihelion, and up to Oct. 11. When I try to connect them with later observations, I see reason to come nearer to Mr. Hind's elements, which give for the node and the inclination respectively

$$346^{\circ}\ 6'\ 58''$$

and

$$37^{\circ}\ 58'\ 59''.$$

I have not yet made any determination of the orbit before perihelion, but from such observations as have come to hand, and others taken very shortly after perihelion, I think I may venture to add that the graphical work suggests the probability of the node having been swept several degrees backwards in longitude between the contact with the Sun's limb recorded by Mr. Gill on the 17th, and the subsequent observations, say up to Sept. 23.

Observations of Comets a, b, c, 1882, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations of Comet *a* with the Naylor equatorial, of Comet *b* with the East equatorial, and of Comet *c* with the South-east equatorial, were all made by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

Observations of Comet a, 1882, with the Naylor Equatorial. Aperture 6 inches.

Greenwich Mean Solar Time.	Obs.	δ − * R.A.	δ − * N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Star.
1882. d h m		m s	′ ″		h m s	° ′ ″	
Apr. 20 12 42	W.C. & T.	+3 37·40	+ 4 56·8	4	19 15 27·52	32 35 2·7	*a*
		−2 41·69	+ 0 16·2	4	19 15 25·87	32 35 10·3	*b*
28 12 49	T.	+1 1·77	+12 18·9	5	20 7 3·51	24 14 35·5	*c*
12 56		−4 46·67	+ 7 21·6	3	20 7 3·04	24 14 20·1	*d*
30 11 14	T.	+1 18·97	+ 8 33·2	2	20 26 1·34	22 15 5·2	*e*
		−1 20·97	−16 8·4	2			*f*
11 59	H.	−1 15·46	−18 7·1	1			*f*
12 30		+1 53·19	+ 5 27·3	2	20 26 35·56	22 11 59·3	*e*
May 2 10 59	T.	+5 32·94	−23 12·9	2	20 49 24·12	20 17 39·0	*g*
10 55		−2 28·91	−11 43·0	1			*h*
11 8		−3 58·15	−13 22·3	1	20 49 32·35	20 17 6·1	*i*
4 11 39	T.	+2 24·39	+ 8 50·7	2	21 19 23·08	18 28 31·2	*k*
		−1 40·27	+ 1 38·0	2	21 19 21·93	18 28 33·9	*l*

Mean Places of the Comparison Stars.

Star.	Star's Name.	R.A. 1882·0	N.P.D. 1882·0	Authority.
		h m s	° ′ ″	
a	54 Draconis	19 11 48·74	32 29 54·0	Greenwich Catalogue, 1860
b	Groomb. 2827	19 18 6·22	32 34 42·4	Radcliffe, 1845
c	Oeltz. Arg. 20152	20 6 0·58	24 2 6·5	Oeltz. Arg. (N), 1842
d	„ 20313	20 11 48·58	24 6 48·5	„
e	Arg. Z. + 67° − 1248	20 24 41·29	22 6 22·3	Bonn Observations, vol. v.
f	Anonymous			
g	Groomb. 3301	20 43 50·17	20 40 42·9	Radcliffe, 1845
h	Anonymous			
i	Groomb. 3359	20 53 29·57	20 30 19·6	Radcliffe, 1845
k	Oeltz. Arg. (N) 22131	21 16 57·91	18 19 32·4	Oeltz. Arg. (N), 1842
l	„ 22261	21 21 1·45	18 26 47·9	„

April 30 and *May* 4.—Comet very faint.

The observations are not corrected for refraction or parallax.

Observations of Comet a, 1882, S.P. *with the Transit Circle.*

Greenwich Mean Solar Time.					Obs.	R.A.			N.P.D. (corrected for Refraction and Parallax).			Remarks.
1882.	d	h	m	s		h	m	s	°	′	″	
May	12	8	52	15	H.	0	14	19·68	−15	32	38·46	Exceedingly faint
	13	9	13	27	A.D.	0	39	31·76	−15	53	49·23	Very faint
	15	9	52	17	T.	1	26	20·62	−17	8	19·55	Very faint indeed
	17	10	24	14	L.	2	6	16·08	−18	59	51·63	
	19	10	48	58	H.	2	38	58·01	−21	20	56·21	Very faint, cloudy
	20	10	58	56	T.	2	52	53·50	−22	40	17·78	Very faint indeed
	23	11	20	37	A.D.	3	26	28·27	−27	5	53·64	Much brighter
	24	11	25	40	B.	3	35	28·72	−28	42	0·19	Very faint, cloudy
	25	11	29	48	H.	3	43	33·70	−30	21	16·78	
	27	11	35	52	A.D.	3	57	31·60	−33	48	34·86	About 5th magnitude
	28	11	37	58	T.	4	3	34·20	−35	36	30·51	
	29	11	39	31	H.	4	9	4·19	−37	27	7·99	Cloudy

Observations of Comet b, 1882, *with the East Equatorial. Aperture* 6·7 *inches.*

Greenwich Mean Solar Time.				Obs.	☌ − ✱ R.A.		N.P.D.			No. of Comp.	Apparent R.A.			Apparent N.P.D.			Star.
1882.	d	h	m		m	s		′	″		h	m	s	°	′	″	
Oct.	25	17	13	A.D.	+1	46·75		−12	5·9	2							*a*
		17	17		+1	41·12		− 8	58·3	4	10	5	20·70	107	24	33·7	*b*
		17	22		−0	17·75		+ 0	10·7	2	10	5	17·96	107	25	1·6	*c*
	29	17	8	A.D.	+0	34·00		+ 3	25·9	2	9	59	27·15	108	53	57·1	*d*
		17	12		−3	11·66		− 5	21·5	3	9	59	22·06	108	54	1·4	*e*
		17	20		+0	39·50		+ 2	0·6	1	9	59	25·06	108	54	18·3	*f*
	30	17	20	H.	+1	12·80		+ 4	16·9	2							*g*
		17	10		+0	26·82		+ 5	47·3	1							*h*
		17	30		−3	53·85		+ 8	22·0	1	9	57	55·41	109	16	31·4	*i*
Nov.	1	15	41	T.	+0	57·50		+12	34·6	3	9	54	45·83	110	0	17·7	*k*
		15	48		−2	21·75		+ 8	59·3	2	9	54	44·10	110	0	22·8	*l*
	7	16	45	H.	+1	27·62		− 5	14·1	2							*m*
		16	37		−2	9·50		− 1	37·2	1							*n*
		16	52		+5	11·50		− 6	14·8	1	9	44	36·05	112	6	37·0	*o*
	8	17	23	A.P.	−1	58·75		+ 6	45·7	2							*p*
					−3	34·00		− 2	4·7	2							*q*
	9	17	32	T.	+1	22·25		− 0	51·8	4	9	40	38·38	112	48	27·9	*r*
					+1	3·50		− 8	17·5	2	9	40	38·40	112	48	23·7	*s*
					+1	39·75		+ 7	53·9	2							*t*
		17	40	A.D.	+1	3·25		− 8	59·7	2	9	36	40·10	113	28	5·5	*u*
		17	48		−0	20·10		+ 4	42·1	5	9	36	38·84	113	28	10·0	*v*
		17	50		+0	46·50		+ 5	37·2	1							*w*
		17	56		−3	1·00		− 0	48·2	2							*x*

Mean Places of the Comparison Stars.

Star.	Star's Name.	R.A. 1882·0.	N.P.D. 1882·0.	Authority.
		h m s	° ′ ″	
a	Anonymous			
b	Lalande 19797	10 3 37·01	107 33 22·4	Lalande
c	Oeltz. Arg. 10428	10 5 33·15	107 24 41·1	Oeltz. Arg. (S), 18
d	Lalande 19699	9 58 50·47	108 50 21·8	Oeltz. Arg. (S)
e	„ 19770	10 2 31·05	108 59 13·4	„
f	„ 19696	9 58 42·88	108 52 8·3	„
g	Anonymous			
h	„			
i	Lalande 19765	10 1 46·56	109 7 59·9	Oeltz. Arg. (S)
k	„ 19559	9 53 45·55	109 47 33·9	Lalande
l	„ 19641	9 57 3·09	109 51 14·2	„
m	Anonymous			
n	„			
o	Oeltz. Arg. 10075	9 39 11·56	112 12 43·1	Oeltz. Arg. (S)
p	Anonymous			
q	„			
r	Oeltz. Arg. 10084	9 39 31·86	112 56 32·5	Oeltz. Arg. (S)
s	„ 10076	9 39 13·09	112 49 10·9	„
t	Anonymous			
u	Oeltz. Arg. 10011	9 35 33·74	113 36 56·5	Oeltz. Arg. (S)
v	„ 10043	9 36 55·83	113 23 19·1	„
w	Anonymous			
x	„			

Nov. 1.—Comet very faint, cloudy.

Nov. 8.—Comet very faint at times.

Nov. 9.—Nucleus of comet very diffused and faint.

Nov. 11.—The comet appeared a faint patch of light; ve difficult to observe; sky thick.

The observations are not corrected for refraction or parall

Observation of Comet b, 1882, *with the Altazimuth.*

From a double observation of Comet *b* made on the mo of Oct. 23 with the altazimuth, with the graduated fr the vertical circle right and left, the following position co for refraction and parallax was obtained:—

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.I
1882. d h m s		h m s	° ′
Oct. 22 16 49 17	H.	10 9 30·98	106 1′

Observations of Comet b, 1882, with the Transit Circle.

Greenwich Mean Solar Time.	Obs.	R.A.	N.P.D. (corrected for Refraction and Parallax).	
1882. d h m s		h m s	° ′ ″	
Nov. 16 17 41 26	L.	9 26 10·00	115 3 34·0	Cloudy
17 17 35 11	A.D.	9 23 50·53	115 21 39·9	Very faint; a difficult observation

Observations of Comet c, 1882, with the S.E. Equatorial. Aperture 12·8 inches.

Greenwich Mean Solar Time.	Obs.	δ−✱ R.A.	δ−✱ N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Star.
1882. d h m		m s	′ ″		h m s	° ′ ″	
Sept. 27 16 28	M	+2 9·80	+2 49·2	1	7 46 47·90	86 28 20·2	*a*
		+0 49·85	+3 7·2	1	7 46 47·78	86 28 17·6	*b*
27 15·58	M	+0 16·01	−0 28·5	13	7 46 44·24	86 26 58·3	*c*
		+0 12·05	+8 5·2	13	7 46 45·34	86 26 55·7	*d*

Mean Places of the Comparison Stars.

Star.	Star's Name.	R.A. 1882·0.	N.P.D. 1882·0.	Authority.
		h m s	° ′ ″	
a	W.B. VII.–1289	7 44 35·37	86 25 24·6	Weisse's Bessel (1)
b	„ 1324	7 45 55·20	86 25 3·9	„
c	„ 1337	7 46 25·51	86 27 20·2	„
d	„ 1339	7 46 30·57	86 18 43·9	„

The observations are not corrected for refraction or parallax.

The initials W.C., A. D., M., T., L., H., A. P., and B., are those of Mr. Christie, Mr. Downing, Mr. Maunder, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. A. Pead, and Mr. Bennett.

Royal Observatory, Greenwich:
1882, *Nov.* 18.

Observations of the Great Comet (b), 1882, *made at the Melbourne Observatory.* By R. L. J. Ellery, F.R.S.

A brilliant comet, first seen in Australia on the morning of Sept. 9, has since been observed here on every occasion when the very cloudy weather which has prevailed would permit.

It became so bright just before perihelion that it was seen at noon with the naked eye within four degrees of the Sun on the 17th, and was observed on the meridian with the transit circle on three days. It is now (Sept. 25) again visible in the early morning. On the 24th it was easily seen with a 4½-in. telescope three hours after sunrise. Its tail was seen 15° long in the bright dawn, and was about 1° wide at the end. This morning, although markedly less bright, it was seen in the same telescope 20 minutes after sunrise.

From observations obtained on the 9th, 13th, and 16th, Mr. E. J. White, [illegible] approximation to an orbit, which is here given:—

T	...	...	...	Sept. 17·175
ϖ	...	...	...	275° 12′
☊	...	...	...	353 38
i	...	...	...	38 10
$\log q$		...	...	7·6906

Motion retrograde.

The exceedingly small perihelion distance, as well as the other elements of this comet, exhibit a decided similarity to that of 1843.

The positions hitherto obtained are attached.

Places of the Great Comet (b), 1882, from Observations made with the North Equatorial, aperture 4½ in., and the Transit Circle of the Melbourne Observatory.

Melbourne M. T. Sept.	Greenwich M. T. Sept.	Obs.	No. of Meas.	Comet – Star. R.A.	Comet – Star. N.P.D.	Comet. Apparent R.A.	Comet. Apparent N.P.D.	Compared with
d h m s	d h m s			m s	′ ″	h m s	° ′ ″	
9 17 24 51·4	9 7 44 56·6	W	4	+1 21·37	+ 1 5·82	9 45 46·41	90 53 36·0	Lamont 2277
13 17 37 21·5	13 7 57 26·7		2	+4 31·11	+15 41·02	10 28 48·49	90 17 49·2	30 Sextantis, Cape 5739
14 23 10 13·7	14 13 30 18·9					10 45 53·34	89 55 47·1	Meridian Transits
15 23 22 36·6	15 13 42 41·8					11 2 14·89	89 29 39·2	”
[illegible]	16 13 59 5·5					11 22 37·75	88 47 55·2	”

[illegible] 15 was observed with great difficulty, the comet being obscured by cloud.

Observations of the Great Comet (b), 1882, *made at the Sydney Observatory.* By H. C. Russell, B.A.

I enclose herewith meridian observations of the comet on four days. They were taken with a Simms' Transit Circle, recently made, and having a 6-in. (clear) objective. The observations have been corrected for all instrumental errors and for refraction. I may mention that the correct longitude for Sydney, $10^h\ 4^m\ 50^s\!\cdot\!8$, is given in the *Nautical Almanac* for 1885; that for 1884 and previous years give the old longitude, which was incorrect. The comet was reported to me on Sept. 7 by Mr. Springwell, chief officer of the steamer *Caraki*. I saw it first on the 8th, but the daylight made it impossible to get stars for comparison with the equatorial. I have examined it with the spectroscope, and find a very bright continuous spectrum without the usual comet lines; but there is one bright line in the yellow which, so far as I have yet been able to ascertain, is coincident with the sodium line. I have not been able to see any dark lines in the continuous spectrum.

The comet presents a magnificent spectacle in the morning now. On Sept. 17 I watched it most of the day; it was like a bright star near the Sun, and with the telescope was seen to have a well-defined nucleus and coma with concentric layers, the outer one being the best defined.

Observations of the Great Comet (b), 1882, *taken on the Meridian at Sydney.*

1882.	R.A. h m s	N.P.D. ° ′ ″
Sept. 18	11 25 33·25	89 10 50·35
19	11 18 7·72	90 3 48·63
20	11 12 19·68	90 51 12·84
21	11 7 30·81	91 34 51·39

Sydney Observatory:
1882, *Oct.* 5.

Observations of the Great Comet (b) 1882, *made at Windsor, New South Wales.* By John Tebbutt.

About noon on the 8th inst. the Government astronomer at Melbourne telegraphed to me "a large comet reported due east at 4h. a.m." Other messages were received during the day from different parts of this colony. From the information thus afforded I was enabled to get observations on the mornings of the 9th and 10th. The nucleus was very large and remarkably brilliant, and the tail about three or four degrees in length. Owing to the strong twilight there were no stars visible sufficiently near to the comet to be within reach of the threads of the filar-micrometer, and I was, therefore, obliged to have recourse to

a square bar-micrometer. By this means I made comparisons on both mornings with star B.A.C., 3303. The transits were observed on opposite sides of the square, and are, therefore, not so satisfactory as I could wish. The following are the results corrected for differential refraction and the comet's proper motion.

	d h m s	d h m s
Windsor Mean Time, 1882, Sept. ...	8 17 54 52	9 17 49 45
Mean R.A. of Star, 1882·0	9 33 49·76	9 33 49·76
Reduction to App. R.A. for date ...	+ 1·84	+ 1·86
Difference R.A. (Comet – Star) ...	+ 3 15·90	+ 11 56·19
Apparent R.A. of Comet	9 37 7·50	9 45 47·81
Mean N.P.D. of Star 1882·0 ...	90° 36′ 27″·6	90° 36′ 27″·6
Reduction to App. N.P.D. for date ...	+ 10·8	+ 10·7
Difference N.P.D. (Comet – Star) ...	+ 21 8·0	+ 16 57·9
Apparent N.P.D. of Comet	90 57 46·4	90 53 36·2
Log. Factor for Parallax in R.A. $\left(\frac{p}{P}\right)$	–8·7115	–8·7187
Log. Factor for Parallax in N.P.D. $\left(\frac{q}{P}\right)$	+9·7365	+9·7370
Number of Comparisons	4	2

The star's mean place has been deduced from the following authorities:—Schjellerup, Radcliffe Observations, 1858, and Annales de l'Observatoire Royal de Bruxelles, Cat. 1874. Up to the present time no further observations could be made, in consequence of fog and cloud, but as the comet is fast approaching conjunction with the Sun, it is probable that it will be visible in the evenings in the west.

Windsor, N. S. Wales:
1882, *Sept.* 15.

Observations of the Great Comet (b), 1882. By A. V. Nursing Row.

A comet is now visible in the eastern heavens before sunrise, and is so conspicuous to the naked eye as to attract general attention. It presents a bright planetary disk, surrounded by nebulosity. On applying higher magnifiers this appearance vanishes, the centre of the head not being occupied by a star-like point.

The head has a border of light surrounding it on the side towards the Sun, and continued round on each side of the tail.

The disk has been undergoing changes of form and apparent diameter for twelve days. The length of the bright part of the tail is between 7° and 8°, above which are narrow rays or streaks of light extending more than 12°—concave towards the south,

and shaped like the tusk of an elephant, the thick part being at the greatest altitude. Observing the comet with the naked eye at the seaside the whole tail took nearly an hour to rise.

Oct. 7.—In telescopic observations some vibration was observed at the head, and for some portion of the tail near the head for only a few seconds. This, we first thought, was owing to some irregular shaky motion of the equatorial, and closely examined the instrument. It was, however, found to be all right, being driven by clockwork, and no accident could be traced in the going of the instrument. The condition of the atmosphere was unusually fine and clear, and no wind. This morning the declination of the comet was $11°$ nearly; right ascension, $10^h\ 16^m\ 31^s$ nearly. Approximate daily variation deduced from the observations—in right ascension, $3^m\ 5^s$; in declination, $+34'\!\cdot\!5$ or $+35'$ nearly.

Our Hindoo astronomers predicted the appearance of a comet in the southern hemisphere in their printed calendar for the present year. As to the identity, they gave no other particulars except that it would possess a bright copper colour like the rising moon, and a long tail. The name given by them to their predicted comet is "Silpacam."

Observatory, Daba Gardens,
Vizagapatam:
1882, *Oct.* 8.

Elements of the Orbit of Comet 1881 *III.* (*Schäberle*). By Henry T. Vivian.

From the three positions of Comet III., 1881, observed by Mr. Tebbutt, Sept. 20 and 29, and Oct. 8 (*Monthly Notices*, vol. xlii., p. 263), I have computed the following parabolic elements:—

$$T = 1881,\ \text{August } 22{\cdot}4093,\ \text{G.M.T.}$$

$$\left.\begin{aligned}\pi &= 334^\circ\ 56'\ 47''\\ \Omega &= \ \ 97\ \ 11\ \ 49\end{aligned}\right\}\ \text{Apparent Equinox, 1881, Sept. 29.}$$

$$i = 39\ \ 37\ \ 1$$

$$\log q = 9{\cdot}8015958$$

Motion retrograde.

A comparison with the middle place (computed—observed) gave—

$$\Delta L = +3''\!\cdot\!8; \qquad \Delta l = -12''\!\cdot\!2.$$

The observations were corrected for aberration, and the longitude of Windsor was taken from the *Nautical Almanac* for the year.

London: 1882, *Nov.* 2.

Sextant Observations of the Great Comet (b), 1882. By Captain G. Pochrane.

(*Communicated by Capt. H. Toynbee, R.N.*)

1882, Oct. 5. 4^h 30^m a.m. saw the comet for the first tin through some breaks in the clouds; could not make any observ tion.

Oct. 5, 18^h 57^m G.M.T., the comet in full view, very larg its bearing from ship S.E., its altitude being 5° 4′, and distan from Moon's upper limb 36° 8′, its tail trending to W.S.W.

Oct. 7, 18^h 5^m G.M.T., in lat. 48° 38′ N. Long. 20° 4′ V Observed altitude of comet's head 4° 25′; length from head to ta 14° 50′; its greatest width 1° 20′; distant from the Moo 16° 35′; Moon's altitude 20° 40′; distance of comet's head fro *Regulus* 23° 54′; altitude of *Regulus* 26° 37′.

The Markings on Jupiter. By W. F. Denning.

In the *Monthly Notices* for Jan. 1882, pp. 97–100, I ga some details of the remarkably swift motion of the bright equ torial spot on *Jupiter*, and, as this curious marking continues be a conspicuous object on the surface of the planet, it may interesting to mention some further observations made here duri the present year.

In my paper above referred to, I gave the period 44^d 10^h 42^m $13^s.3$ as that in which the great velocity of bright spot enabled it to complete a revolution of *Jupiter* latively to the red spot, and I gave a list of conjunctions 1882 founded on this period. These were observed here as as circumstances permitted. For the last half of the yea following were the predicted dates of these conjunctions.

				h	m	s
1882, Aug. 3	...	...		15	14	7
Sept. 17	...	...		1	56	20
Oct. 31	...	...		12	38	33
Dec. 14	...	...		23	20	47

The phenomenon in August really occurred about 1′ later than predicted from observations obtained her lows:—

			Red Spot on C.M.		White Spot o	
			h	m	h	m
1882, Aug. 5	...	...	15	12	15	4
7	...	...	16	47	16	

On August 5 the white spot preceded the middl by eight minutes, so that, allowing for the diurn

13^m 24^s by the former, the conjunction must have occurred on Aug. 5 at 0^h 44^m.

In September the conjunction took place about 1^d 5^h later than that computed. I made observations on Sept. 13 and 15, and on Sept. 17 the markings were observed by Mr. A. Stanley Williams at Brighton :—

		Red Spot on C.M.	White Spot on C.M.
		h m	h m
1882, Sept. 13	... ..	12 28	13 28
15	... ...	14 6	14 36
17	... ...	15 38 5	15 47

On Sept. 17 the white spot followed the red 8·5 minutes, so that it must have arrived at conjunction on Sept. 18 at 7^h. Near the epoch of the last conjunction at the end of October I obtained the following results :—

		Red Spot on C.M.	White Spot on C.M.
		h m	h m
1882, Oct. 25	.. ...	16 59	18 32
29	... ...	10 20	10 52
30	... ...	16 10	16 22
Nov. 1	... ...	17 54	17 40

On Oct. 30 at 16^h 22^m the white spot *followed* the red twelve minutes, so that the conjunction is indicated for Oct. 31, 13^h 51^m.

On Nov. 1 at 17^h 40^m the white spot *preceded* the red fourteen minutes, so that the phenomenon is shown for Oct. 31, 15^h 36^m. The mean of the two values is Oct. 31, 14^h 43^m, which, I believe, must be very near the truth, as the pair of observations agree very closely, and were made under extremely favourable circumstances. This conjunction has, therefore, occurred within about two hours of the epoch given last January, and thus the period of 44^d 10^h 42^m $13^s \cdot 3$ derived from observations extending from Nov. 19, 1880, to Dec. 24, 1881, during which the white spot performed nine revolutions, is well confirmed. The observations of successive conjunctions show that there is a considerable departure from the average period in several cases. Thus the conjunction of Sept 26, 1881, 7^h 32^m, and Nov. 10, 11^h 3^m, give a period as long as 45^d 3^h 31^m, whereas that of Sept. 18, 1882, 7^h, and Oct. 31, 14^h 43^m, was only 43^d 7^h 43^m, showing a difference of nearly two days. Since Nov. 19, 1880, which was the first conjunction of the two spots ever observed here, the great velocity of the white spot has enabled it to complete 16 revolutions of *Jupiter* relatively to the position of the red spot. The number of rotations performed during the entire period from Nov. 19, 1880, 9^h 23^m, to Oct. 31, 12^h, is 1,719 for the red spot and 1,735 for the white spot.

The red spot has grown extremely faint, and its early disappearance seems very possible. On the other hand, the brilliant white spot fully maintains the striking appearance it presented in 1880, and gives promise of remaining in view for a considerable time. Should the two markings continue visible during the ensuing year, they may be observed at or near conjunction at the following times:—

				h	m	s
1883. Jan. 28	...	...		10	3	0
Mar. 13	...	...		20	45	13
Apr. 27	...	...		7	27	27
June 10	...	...		18	9	40
July 25	...	...		4	51	53
Sept. 7	...	...		15	34	7
Oct 22	...	...		2	16	20
Dec. 5	...	...		12	58	33

The bright spot is very variable. There is a wide range in its maxima and minima. On three occasions I have failed to see any sign of it in my 10-inch Browning Reflector, though, at the time of maximum, I have seen it distinctly with a $2\frac{1}{8}$-inch Ramsden object glass. This spot is the central one, and the largest of three near together on the equatorial border of the great southern belt, and is the brightest and most conspicuous of its class. It must not be confused with many other varieties of white spots distributed over the surface of *Jupiter*, which are far less permanent and, in some instances, give different periods of rotation.

Ashley Down, Bristol:
1882, *Nov.* 2.

The Fireball Radiants of August 9–11. By W. F. Denning.

In addition to the brilliant shower of Perseids which returns every year on August 9–11 there are many other meteor streams which, though of minor character, are yet distinctly marked, and occasionally supply fireballs of considerable size. I recently examined a large number of meteor catalogues, and projected the paths of many fireballs recorded on the nights of August 9–11, and, as may be readily inferred, the great majority of these proved to be Perseids, though several other radiants were well indicated by the directions of their flights. I found good showers from points near γ *Cephei*, α *Cygni*, γ *Andromedæ*, γ *Capricorni*, and o *Draconis*; also more doubtful positions at $100°+63°$, $249°+48°$, $341°+34°$, $257°+13°$, $192°+79°$, $253°-20°$,

355° − 8°, and 337° − 28°. The two former I regard as particularly well established, and they correspond with showers of ordinary meteors. It may, therefore, be interesting to refer to them in detail, as they are very likely to come under repeated observation in future years.

I. The shower near γ *Cephei* is at 335° + 73°. The paths of sixteen fireballs were found to indicate this position very exactly. Of these the observed flights of thirteen are shown on the accompanying diagram. They were chiefly observed by members of the Italian Meteoric Association in 1872, but the shower is

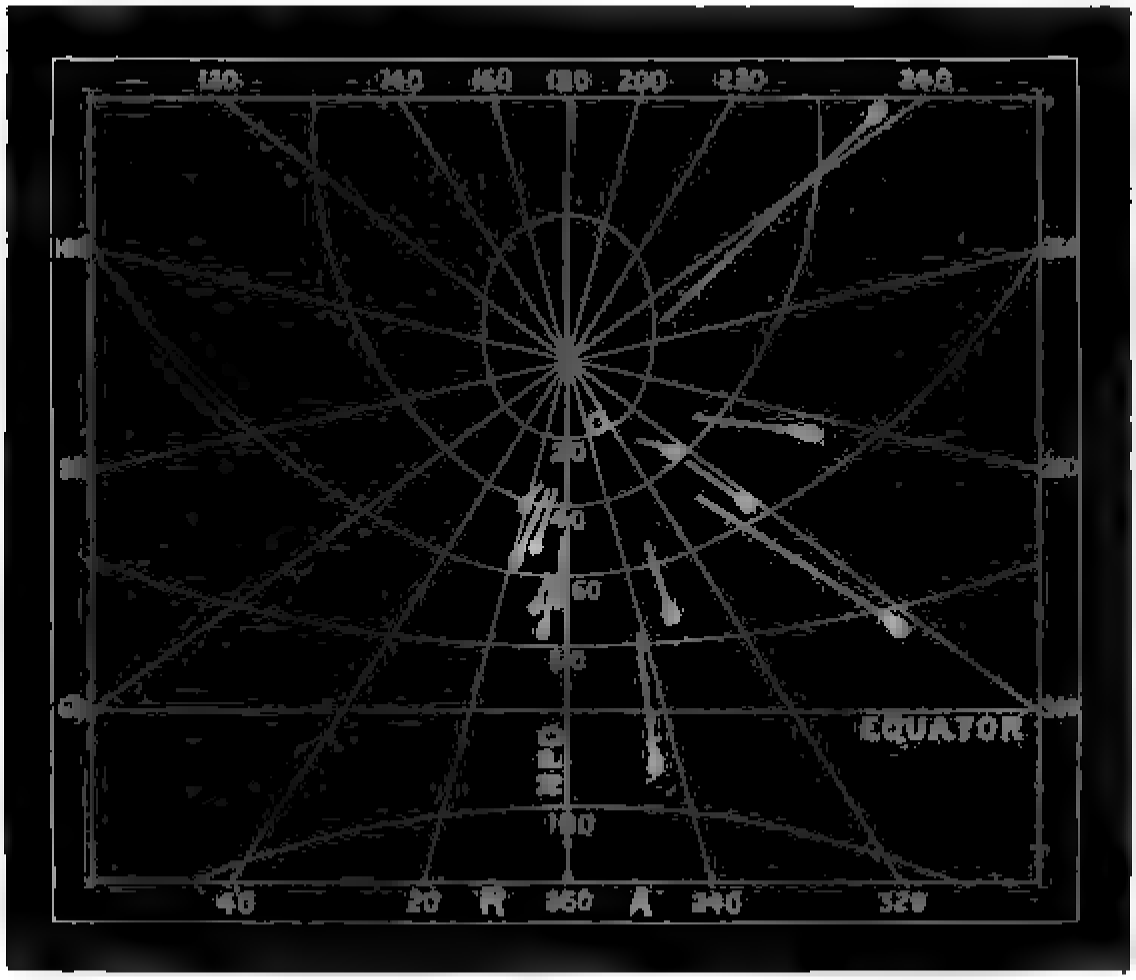


Fig. 1.—Paths of 13 Fireballs (Cepheids), Aug. 9–11.

amply confirmed from other sources. On August 10, 1869, Mr. Backhouse, at Sunderland, saw a bright stationary meteor at 337° + 78°, which obviously belonged to this stream, and on August 10, 1874, a fireball was observed by Prof. Herschel, at Newcastle-on-Tyne, and Mr. Clark, at York, which gave a radiant point at 352° + 72°.* Another meteor doubly observed on August 11, 1871, at Greenwich and Hawkhurst, gave a radiant at 350° + 70° (Waller), "the recorded paths being in very good accordance with a radiant near ψ or ι *Cephei*." † This position

* British Association Report on Luminous Meteors for 1876, p. 138.
† *Ibid* 1874, pp 278 and 285.

has also been derived by several meteor observers as giving a contemporary display with the Perseids:—

August 9–12	...	355° + 81° Heis (113 meteors)
5	...	315 + 80 Schiaparelli and Zezioli
6–31	...	335 + 67 Greg and Herschel
12	...	330 + 70 Denning
17	...	335 + 69 Corder
August	...	340 + 67 Greg (1874)

The mean of the six positions is 335° + 72°·4, which is almost coincident with the fireball radiant above referred to. The point of divergence as given by different observers does not agree very closely, but the great altitude of this shower readily explains this, for a radiant near the zenith is always much more difficult to determine with precision than one near the horizon. I believe that the several positions included in the list certainly relate to one and the same stream, and this is rendered additionally probable by the fact that the average place exhibits so close an agreement with the fireball radiant which has been quite independently derived. And if further proof is needed as to the existence of this prominent shower of Cepheids, we have it in the observations of Mr. Clark, at York, on August 5–12, 1871, who, in summarising his results,* says, "A remarkable feature was the outlying radiants, one of which was situated at or near θ *Cassiopeiæ*, and another near the star C of *Camelopardi*. The radiant between δ *Cygni* and γ *Draconis* was very well marked, *also a radiant near* γ *Cephei* [353° + 73°], where an almost stationary meteor was observed." The latter shower is unquestionably identical with the one we have now been describing, as the position and epoch are the same.

II. The fireball radiant near α *Cygni* is at 312° + 50°, which is already well known as an apparently long-enduring shower visible chiefly in the months of July and August. Mr. Greg † places the centre at 309° + 48° from a mean of 15 different estimates, and calls it the *Cygnids I.* It is certainly a stream of considerable richness, and one which, though supplying many shooting stars of ordinary type, is also notable for the occasional exhibition of very large meteors. In looking through the published observations of August 9–11, I found the paths of twelve fireballs which conformed more or less exactly with this radiant, and the observed positions of nine of these are projected on the following diagram.

* *Nature*, August 17, 1871.

† "Table of Radiant Positions and Durations of Meteor Showers visible in the Northern Hemisphere," published in the B. A. Report on Meteors for 1875, p. 159, Radiant No. 81.

Though this shower has not, I believe, been hitherto noticed as affording a conspicuous display of brilliant meteors, it has been seen as a well-defined radiant by nearly all regular observers of meteor showers. Greg and Herschel gave the centre as at $310^\circ+47^\circ$ (July 6–August 4), Schiaparelli and Zezioli at $304^\circ+49^\circ$ (July 31) and $304^\circ+44^\circ$ (August 4), Corder at $304^\circ+48^\circ$ (August–September), while the writer found it at $315^\circ+50^\circ$ (July–August 1877). Tupman gives a shower at $310^\circ+58^\circ$ (August 13), but this is too far N. to be fairly con-

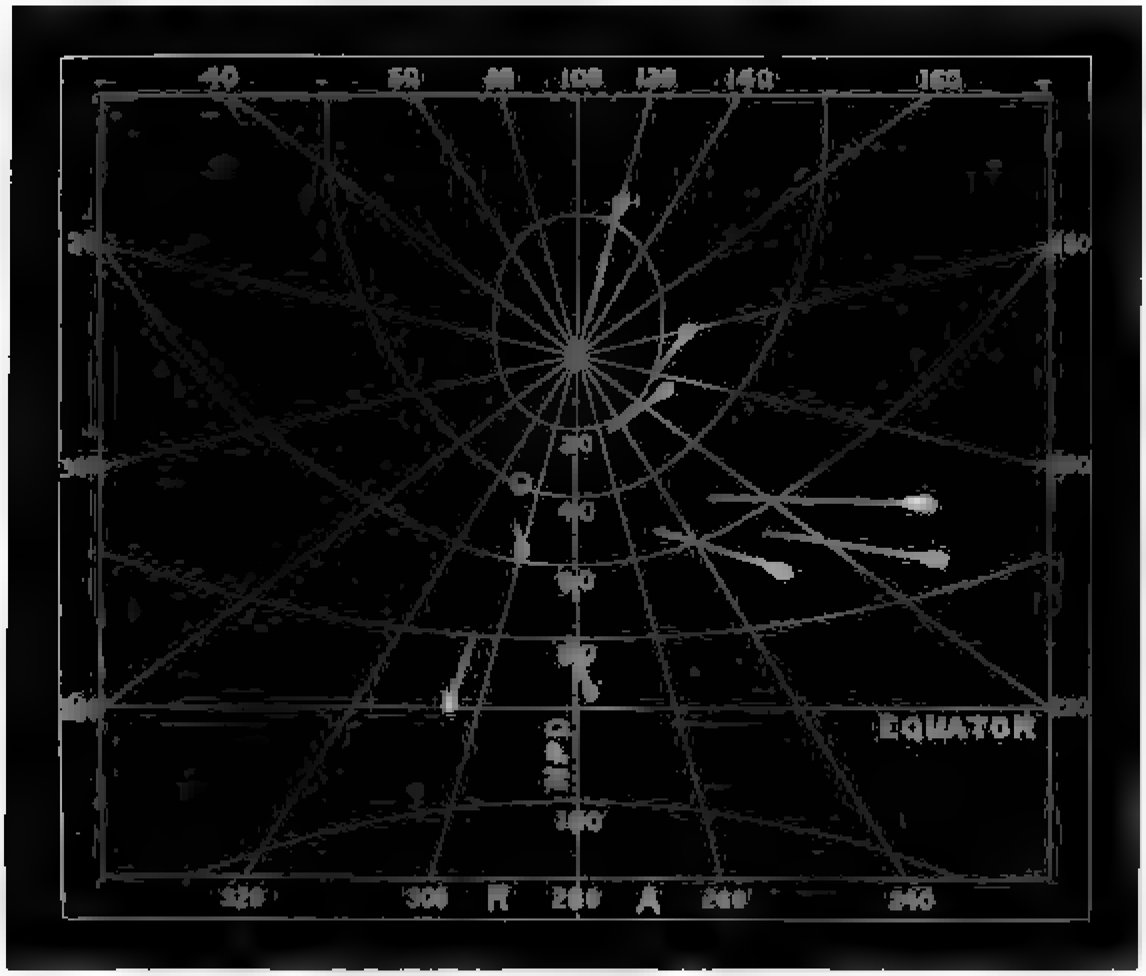


Fig. 2.—Paths of 9 Fireballs (Cygnids), Aug. 9–11.

sidered a return of these Cygnids. It undoubtedly refers to a northerly radiant in *Cepheus*, which we shall refer to later on.

In *Cygnus* and the immediate region hereabout there is a large number of contemporary showers, visible in July–August, which are very liable to confuse observers. Some of these showers lie in the more southerly part of *Cygnus*, others cluster about *α Cygni*, and others again extend northward into *Cepheus*; indeed, this region of the heavens appears to be so rich in meteor streams at this epoch that it is extremely difficult to disassociate them. In comparing the radiants given in various catalogues, they seem to be so numerously distributed in this quarter that it is impossible to group them into reliable positions. I believe, however, there are three active showers here to which the

majority of these observations have reference, and I have derived the following mean positions for July–August:—

(1)	$311^\circ.5+47^\circ.0$	α Cygnids, mean of 18 radiants.
(2)	$310.4+36.0$	ϵ Cygnids, mean of 14 radiants.
(3)	$311.8+62.3$	α Cepheids, mean of 14 radiants.

There are other and probably less active displays at this period of the year, both from *Cygnus* and *Cepheus*, while E. and W. in *Lacerta* and *Lyra* the sky is teeming with meteor showers. The shower at $311^\circ.8+62^\circ.3$ (α Cepheids), is quite a separate display to the shower at $335^\circ+73^\circ$ (γ Cepheids), though its contemporary activity is evident. And the pair of showers near α and ϵ *Cygni* are no doubt equally distinct though not always distinguished from each other owing to their proximity of position. There is, however a difference of 11° in declination, which is sufficiently large to prevent confusing the meteors of the two systems, especially when the motions are chiefly in R.A., and the meteors appear in the region of their radiant point.

Amongst the bright meteor showers of August 9–11 I may refer also to the γ Andromedes ($12^\circ+30^\circ$) and o Draconids ($284^\circ+62^\circ$), which are both well ascertained radiants included in Mr. Greg's general catalogue (1875), where they are placed at $7^\circ+33^\circ$ and $282^\circ+60^\circ$ from a mean of twelve positions each. It is to these and to the contemporary showers of Cepheids and Cygnids that many fine meteors (non-Perseids) of the August epoch owe their origin. Observers of future returns of the Perseids will, therefore, do well to note the paths of such fireballs as are not conformable to *Perseus*, so that they may be attributed their separate radiant points, and the investigation of these interesting minor showers carried yet further.

Bristol: 1882. *Nov.* 1.

The Electric Light in Observatories. By W. S. Franks.

I wish to bring under the notice of this Society a simple, cheap, and efficient means of obtaining illumination; equally applicable to the micrometer, divided circles, clock face, reading desk, &c. The light is so thoroughly successful that I feel sure it only requires to be made known, and I have Canon Beechey's permission to state freely what I saw of its action in his observatory (Hilgay Rectory, Norfolk) during a long night's work. Two of Swan's smallest incandescent lamps were in use, one for the reading desk and the other in micrometer; and, as they are never required to be both used at once, a switch directs the current from one to the other. The battery consists of four pint-size bichromate cells, the plates being 6 in. × 2 in. A

wooden frame supports the plates, and a catgut line is fastened to its centre, then passes over a brass pulley, and is attached to a leaden counterpoise, which just balances it. Thus it will be seen that the plates can be depressed or raised, and the light correspondingly regulated to the utmost nicety. To give an idea of how the light can be reduced, I measured the 13 mag. *comes* to P. I. 145 *Piscium* with ease, with bright field illumination (the telescope is a 10-inch Calver). The lamp over the books was very beautiful, and pleasant to read by; and an abundant length of flexible silk-covered wire enabled it to be carried about anywhere in the observatory, for reading off the circles of equatorial, clock dial, &c. A spare battery is in reserve, in case the light diminishes after long use, but the worked battery is as good as ever after a few minutes' rest. It is necessary to be careful about the carbon connection; but a slip of platinum foil next the carbon, and a slip of brass between it and clamp screw, makes all safe against oxidation. It is almost unnecessary to add that I am now converting my own from oil to electricity, and earnestly advise others to do the same.

Leicester: 1882, *Nov.* 1.

On a Probable Assyrian Transit of Venus. By the Rev. S. J. Johnson, M.A.

That a solar spot 1′ of arc in diameter may be perceived by unaided vision will readily be granted. Consequently little notice need be taken of M. Arago's remark that "naked-eye observers of the transit of 1761 made more use of their imagination than of their eyes," especially as distinct mention is made of *Venus* being so seen by Mr. Holland at Quebec in 1769, and at Maros Vasarhely and other places in 1874. Conjunctions of *Venus* and the Sun are noted down in Stoffler's Ephemerides at the time of the transits of 1518 and 1526; but even if the idea of one had occurred, his tables show too great a distance between the planet and the Sun. As to the solar spot said to have been seen by Averrhoës in 1161, when *Venus* was in conjunction, it may be remarked that in the list of the transits given in Fergusson's Astronomy from La Lande's tables, only a single transit seems to have occurred in the twelfth century, in 1153. There is, however, one instance in very ancient times which may turn out to be a transit. A broken Assyrian tablet, just mentioned in a note of two lines by Rev. Mr. Sayce in "Nature" some years back, may perhaps deserve more attention than it has received. As the tablet is concerned with the planet *Venus*, and as the following succession of broken lines occurs, "the planet *Venus*"—"it passed across"—"the Sun"—"across the face of the Sun," it naturally occurs to try to fill up each hiatus. But it seems very difficult to explain the last sentence otherwise than by supposing that an actual transit is recorded, which, it seems,

must be before the sixteenth century B.C. It reads like a case of an *entire* transit visible in Babylonia.

Melplash Vicarage, Bridport:
1882, *Nov.* 7.

The Solar Eclipse of 1882, *May* 17, *observed at Meerut, India.* By Major Alex. Burton-Brown, R.A.

On the morning of May 17, 1882, a party of officers, under my supervision, set to work to construct a small observatory of laths, and arranged our telescope on a fixed pillar, so that the Sun might be projected on a screen of paper forming a plane perpendicular to the axis of the telescope, and moving with it, all other light being shut off from above except what passed through the telescope by means of another upper screen attached thereto.

The telescope was a refractor, with a fine object-glass of $2\frac{3}{4}$ in., and a power of 50. The projected image was 6 inches in diameter.

First contact was very clearly marked on the screen at $11^h\ 58^m\ 36\frac{1}{2}^s$ local time, but the exact moment of maximum eclipse cannot be certainly stated, but is believed to have been at about $14^h\ 7^m$. A sketch was made when the Moon was just commencing to occult the large group of Sun spots, the largest of which were nearly as black as the Moon; far darker, by comparison, than I have ever noticed them in former eclipses. A few minutes after we clearly noticed the retrogression of the shadow.

The rugged edge of the Moon was seen to great perfection, as also first contact with great accuracy on the paper screen; far more so than by direct-vision observers with dark glasses. The occultation of the spots and the comparative degree of darkness between them and the Moon were most clearly noticed. Very faint clouds were noticed, but not in the vicinity of the Sun, at the commencement of the eclipse. As the eclipse progressed, they increased and approached the Sun apparently, and about 2 o'clock a few passed over the Sun. As the eclipse passed off, so the clouds receded and disappeared entirely before the eclipse terminated.

The maximum temperature in the sun was $159\frac{1}{2}^\circ$ F. The temperature in the shade was 102° F. at noon, and 93° F. at 2 p.m., showing a fall of at least 9° F. during the eclipse.

I would observe that in any place where a clear bright sky was obtainable, and where the sun was at a considerable altitude during the Transit of *Venus*, unscientific observers might do good service with 3-in. or 4-in. refractors and powers of 35 to 60, by marking the track of the planet on a 6 or 8-inch image projected on paper—say every quarter of an hour. These, when compared and tabulated, would form a useful auxiliary to the regular observations.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. DECEMBER 8, 1882. No. 2.

E. J. STONE, M.A., F.R.S., President, in the Chair.

John Wilson Appleton, 12 Amberley Street, Toxteth Park, Liverpool; and
The Hon. Cecil Duncombe, Nawton Grange, Nawton, North Yorkshire,

were balloted for, and duly elected Fellows of the Society.

On Newton's Solution of Kepler's Problem. By Professor J. C. Adams, M.A., F.R.S.

Of all the methods which have been proposed for the solution of this problem, that which leads most rapidly to a result having any required degree of precision may be briefly explained as follows:—

The equation to be solved by successive approximations is

$$x - e \sin x = z,$$

where z is the known mean anomaly, e the eccentricity, and x the eccentric anomaly to be determined.

Suppose x_0 to be an approximate value of x, found whether by estimation, by graphical construction, or by a previous rough calculation, and let

$$x_0 - e \sin x_0 = z_0.$$

Then if

$$\delta x_0 = \frac{z - z_0}{1 - e \cos x_0},$$

and

$$x' = x_0 + \delta x_0,$$

x' will be a much more approximate value of x than x_0.

Similarly, if we put

$$x' - e \sin x' = z',$$

and if

$$\delta x' = \frac{z - z'}{1 - e \cos x'}$$

and

$$x'' = x' + \delta x',$$

x'' will be a much more approximate value of x than x'; and so on, to any required degree of approximation.

If the error of the assumed value x_0 be supposed to be of the order i, when e is taken as a small quantity of the first order, then the error of the value x' will be of the order $2i + 1 = i'$ suppose, similarly the error of the value x'' will be of the order $2i' + 1 = 4i + 3$, and so on, so that the order of the error is more than doubled at each successive approximation.

The above explains the immense advantage of this process over the use of series proceeding according to powers of e, when great precision is required in the result; since, in this latter method, the addition of a new term only increases the order of the error by unity.

The degree of rapidity of the approximation may be still further increased by the following slight modification of the above process.

Starting, as before, with the value x_0, and calling $z - z_0 = \delta z_0$, we should obtain a much more accurate value than before of the correction δx_0 to be applied to x_0, by putting

$$\delta x_0 = \frac{z - z_0}{1 - e \cos (x_0 + \frac{1}{2} \delta x_0)} = \frac{\delta z_0}{1 - e \cos (x_0 + \frac{1}{2} \delta x_0)}.$$

Now, e being supposed to be small, δz_0 is an approximate value of δx_0, and may be written for it in the small term in the denominator.

Hence, if we put

$$\delta x_0 = \frac{\delta z_0}{1 - e \cos (x_0 + \frac{1}{2} \delta z_0)},$$

$$x' = x_0 + \delta x_0,$$

x' will be a nearer approximation to the true value of x than was obtained before by the corresponding operation.

Similarly, if

$$x' - e \sin x' = z',$$

and

$$z - z' = \delta z',$$

and if

$$\delta x' = \frac{\delta z'}{1 - e \cos (x' + \frac{1}{2}\delta z')},$$

then

$$x'' = x' + \delta x'$$

will be the next approximate value of x, and the process may be continued as far as we please.

If the error of x_0 be of the order i, that of x' will now be of the order $2i+2$, that of x'' will be of the order $2(2i+2)+2 = 4i+6$, and so on, so that the degree of rapidity of the approximation is still greater than before.

If we chose to take the mean anomaly itself as the first approximate value of the eccentric anomaly—that is, if we put

$$x_0 = z,$$

we should have

$$z_0 = z - e \sin z,$$

and the value of δx_0 given by the first method would be

$$\delta x_0 = \frac{e \sin z}{1 - e \cos z},$$

while that given by the second and more accurate method would be

$$\delta x_0 = \frac{e \sin z}{1 - e \cos (z + \frac{1}{2} e \sin z)},$$

and the error of $x' = x_0 + \delta x_0$ would be of the 3rd order in the former case, and of the 4th order in the latter.

In practice, however, a much nearer first approximate value of x may be always found by inspection, and of course the smaller the error of this value is, the more rapid will be the rate of the subsequent approximations.

The methods above explained have been long known. The first method is given at p. 41 of Thomas Simpson's "Essays on several Subjects in Speculative and Mixed Mathematics," published in 1740; and Gauss' method given at pp. 10–12 of the "Theoria Motus," published in 1809, is essentially the same.

The second method, or rather the modification of the first, is given by Cagnoli in his "Trigonométrie," at pp. 377, 378 of the first edition, published in 1786, and at pp. 418–420 of the second edition, published in 1808.

Now, my object in the present note is to point out that the first method explained above is exactly equivalent to that given by Newton in the "Principia," at pp. 101, 102 of the second edition, and at pp. 109, 110 of the third edition, when Newton's expressions are put into the modern analytical form.

None of the subsequent authors, however, mentions this method as being Newton's, the unusual form in which Newton's solution is given having, no doubt, caused them to overlook it.

F 2

In the first edition of the "Principia" a modification of the method is given which was, I have no doubt, intended by Newton to be equivalent to the second method given above; but by some inadvertence, instead of the denominator of $\delta x'$ being

$$1 - e \cos (x' + \tfrac{1}{2} \delta x'),$$

when expressed in the above notation, he takes it to be what is equivalent to

$$1 - e \cos (x' + \tfrac{1}{2} e \sin x'),$$

which is only true for the first approximation when x_0 is taken $= z$.

In the second and third editions this error is corrected, but Newton contents himself with the more simple expression given by the first method.

We need not be surprised that Newton should have employed this method of solving the transcendental equation

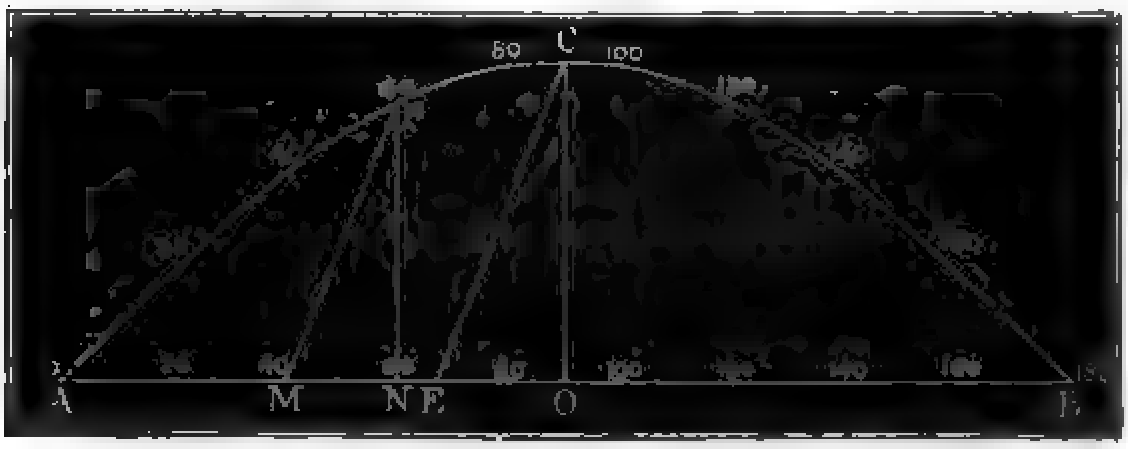
$$x - e \sin x = z,$$

since the method is identical in principle with his well-known method of approximation to the roots of algebraic equations.

For convenience of calculation, the approximate values x_0, x', x'', &c., should be so chosen that their sines may be taken directly from the tables without interpolation; and, since each approximation is independent of the preceding ones, this may always be done if x' be taken equal, not to $x_0 + \delta x_0$ itself, but to the angle nearest to $x_0 + \delta x_0$ which is contained in the tables, and if similarly x'' be taken equal to the tabular angle which is nearest to $x' + \delta x'$, and so on. In the first approximation it will be amply sufficient to use 5-figure logarithms, but in the subsequent ones tables with a larger number of decimal places should be employed.

A first approximate value of the eccentric anomaly corresponding to any given mean anomaly may be found by a very simple graphical construction, provided we have traced, once for all, a curve in which the ordinates are proportional to the sines of the angles represented on any given scale by the abscissæ.

This curve is commonly called "the curve of sines." It will be sufficient to trace the portion of the curve for which the ordinates are positive.



Let A O B be the line of abscissæ, and let A O be taken equal to O B, and let each of them be divided into 90 equal parts representing degrees of angle. Let A N be any abscissa representing the angle x, and let the corresponding ordinate N P $=c \sin x$; then the greatest ordinate will be O C $=c$, corresponding to the abscissa A O.

Suppose the curve line A P C B to be divided into 180 parts which correspond to equal divisions on the line of abscissæ A N O B.

Then if E be taken in A O so that E O $= e \times 57{\cdot}296$ divisions, or if A E $=90-e \times 57{\cdot}296$ divisions, and if C E be joined and P M be drawn parallel to it through P meeting the line of abscissæ in M, then A M will represent the mean anomaly corresponding to the eccentric anomaly represented by A N.

For, since the triangles P M N, C E O are similar,

$$\frac{\mathrm{MN}}{\mathrm{EO}}=\frac{\mathrm{PN}}{\mathrm{CO}}=\sin x,$$

and therefore M N $=$ E O $\sin x = 57{\cdot}296\ (e \sin x)$.

Hence M N represents the number of degrees in $x-z$, and therefore A M represents the mean anomaly z.

Conversely, if A M represents any given mean anomaly, then if M P be drawn parallel to E C, it will cut the curve in the point P corresponding to the eccentric anomaly.

By the employment of a parallel ruler we may find the eccentric anomaly corresponding to any given mean anomaly, or conversely, without actually drawing a line. For if we lay an edge of the ruler across the points E C and then make a parallel edge to pass through the point M it will cut the curve in the point P required.

Thus we may always find a first approximate value of the eccentric anomaly, without making repeated trials, whether the eccentricity be large or small.

I described this graphical method of solving Kepler's problem at the Birmingham meeting of the British Association in 1849. It is referred to in a paper by Mr. Proctor in vol. xxxiii. of the *Monthly Notices*, p. 390.

The construction is so simple that it has probably been proposed before, though I have nowhere met with it.

Note on Professor Zenger's solution of the same problem given in Number 9 of the last volume of the "Monthly Notices."

The only peculiarity in this solution is in the mode of obtaining the first approximate value employed. The subsequent approximations are carried on by means of the first method given above. Professor Zenger's process may be represented in a slightly different form as follows:—

We have

$$x-z=e \sin x,$$

and therefore

$$\sin(x-z)=\sin(e\sin x)=e\sin x\left\{1-\frac{1}{6}e^2\sin^2 x+\frac{1}{120}e^4\sin^4 x-\text{etc.}\right\},$$

or

$$\sin(x-z)=f\sin x;$$

where

$$f=e\left\{1-\frac{1}{6}e^2\sin^2 x+\frac{1}{120}e^4\sin^4 x-\text{etc.}\right\}.$$

Hence

$$\tan(x-z)=\frac{f\sin z}{1-f\cos z}.$$

Now, an approximate value of f is e, and the error in the determination of $\tan(x-z)$ if we were to put

$$\tan(x-z)=\frac{e\sin z}{1-e\cos z}$$

would be of the 3rd order in e.

If we determine f so that the error in the determination of x shall vanish when

$$x=\frac{\pi}{2},$$

we shall have

$$f=e\left\{1-\frac{1}{6}e^2+\frac{1}{120}e^4-\text{etc.}\right\}=\sin e,$$

and the approximate equation for finding $x-z$ becomes

$$\tan(x-z)=\frac{\sin e\sin z}{1-\sin e\cos z}.$$

The error still remains in general of the 3rd order in e, but the maximum error will be smaller than when f is taken $=e$.

The value of x given by this equation is readily seen to be equivalent to that given by Professor Zenger's equation,

$$\cot x=\cot z-\frac{e\operatorname{cosec} z}{1+\frac{1}{6}\sin^2 e+\frac{3}{40}\sin^4 e+\text{etc.}};$$

where we may remark that the quantity

$$\frac{1}{1+\frac{1}{6}\sin^2 e+\frac{3}{40}\sin^4 e+\text{etc.}}$$

is equivalent to

$$\frac{\sin e}{e}, \text{ or to } \quad 1-\frac{1}{6}e^2+\frac{1}{120}e^4-\text{etc.},$$

a series which converges much more rapidly than the series for its reciprocal, employed by Professor Zenger.

A still more advantageous result may, however, be obtained by determining f so that the error may vanish both when

$$x=\frac{\pi}{3},$$

and when

$$x=\frac{2\pi}{3},$$

that is when

$$\sin x=\frac{\sqrt{3}}{2},$$

so that

$$f=e\left\{1-\frac{1}{8}e^2+\frac{3}{640}e^4-, \text{etc.}\right\}.$$

The order of accuracy of the approximation will not be altered by confining ourselves to the first two terms of this value of f, so that we may take

$$\tan(x-z)=\frac{e\left(1-\frac{1}{8}e^2\right)\sin z}{1-e\left(1-\frac{1}{8}e^2\right)\cos z}, \text{ nearly.}$$

The error is still of the 3rd order, but its maximum amount is less than before.

If f be taken

$$=e\left\{1-\frac{1}{6}e^2\sin^2 z\right\},$$

and

$$\tan(x-z)=\frac{f\sin z}{1-f\cos z},$$

the error in the determination of $\tan(x-z)$, and therefore in the determination of x, will be only of the 4th order.

There are several misprints and some errors of calculation in Professor Zenger's paper, on which I need not dwell. *True* anomaly in line 8 of the paper should be *eccentric* anomaly, and the same error occurs on p. 448.

Observations of the Great Comet (b) 1882 *made at the Cambridge Observatory with the Northumberland Equatorial and Square Bar Micrometer.*

(*Communicated by Professor J. C. Adams, M.A., F.R.S.*)

Greenwich Mean Time.	Aberration Time.	Apparent R.A.	Parallax.	Apparent Decl.	Parallax.	Comp. Star.	No. of Comp.
1882.		h m s	s	° ′ ″	″		
Oct. 25·70448	−·00842	10 5 20·019	−0·179	−17 24 19·81	+5·39	*a*	5
		19·724		34·22		*b*	5
·72215	−·00842	10 5 17·982	−0·157	−17 24 45·81	+5·47	*a*	5
		18·029		59·33		*b*	5
		c+1 43·167		*c*+11 37·78		*c*	5
·73970	−·00842	10 5 16·598	−0·132	−17 25 8·30	+5·54	*a*	5
		16·523		20·72		*b*	5
		c+1 41·831		*c*+11 17·89		*c*	5
26·69713	−·00843	10 3 54·135	−0·183	−17 47 3·22	+5·37	*d*	5
·70755	−·00843	10 3 53·366	−0·171	−17 47 15·67	+5·42	*d*	5
		e+1 8·172		*e*+ 3 29·70		*e*	5
·72058	−·00843	10 3 52·289	−0·154	−17 47 29·28	+5·48	*d*	5
		e+1 7·166		*e*+ 3 16·46		*e*	5
		f+0 49·037		*f*+ 8 19·24		*f*	5
29·71667	−·00847	9 59 25·380	−0·144	−18 54 17·89	+5·52	*g*	5
·72439	−·00847	9 59 24·524	−0·133	−18 54 23·54	+5·55	*h*	6
30·71791	−·00848	*i*+2 4·185	−0·137	*i*− 9 49·70	+5·54	*i*	5
·72769	−·00848	*j*+1 12·289	−0·123	*j*− 4 36·50	+5·57	*j*	5
·73965	−·00848	*i*+2 2·318	−0·105	*i*−10 19·85	+5·61	*i*	5
		j+1 11·034		*j* −4 49·15		*j*	5
Nov. 1·71772	−·00850	9 54 42·313	−0·127	−19 59 58·92	+5·57	*k*	7
		42·523		58·65		*l*	7
2·70519	−·00851	9 53 6·800	−0·139	−20 21 22·35	+5·54	*m*	2
·70914	−·00851	9 53 6·420	−0·134	−20 21 27·34	+5·56	*n*	3
·71242	−·00851	9 53 5·772	−0·130	−20 21 32·08	+5·57	*o*	6
5·67997	−·00854	*p*−0 13·977	−0·158	*p*− 7 6·77	+5·48	*p*	5
·70310	−·00854	9 47 59·632	−0·126	−21 25 6·20	+5·59	*q*	5
·70574	−·00854	9 47 58·761	−0·122	−21 25 3·78	+5·60	*r*	3
7·69393	−·00855	9 44 26·324	−0·128	−22 6 32·87	+5·59	*s*	5
·71300	−·00855	9 44 24·540	−0·099	−22 7 3·30	+5·66	*t*	6
		24·366		6 54·47		*s*	6
8·69769	−·00855	9 42 35·101	−0·117	−22 27 11·11	+5·62	*u*	6
		34·674		8·88		*v*	6

Greenwich Mean Time.	Aberration Time.	Apparent R.A.	Parallax.	Apparent Decl.	Parallax.	Comp. Star.	No. of Comp.
1882.		h m s	s	° ′ ″	″		
Nov. 9·68469	−·00856	9 40 43·331	−0·133	−22 47 12·04	+5·58	*w*	6
		42·582		12·41		*x*	6
·69780	−·00856	9 40 41·674	−0·111	−22 47 29·60	+5·64	*w*	6
		41·184		28·95		*x*	6
10·66723	−·00857	9 38 48·263	−0·150	−23 7 4·65	+5·53	*y*	5
		47·828		5·01		*x*	5
·67525	−·00857	9 38 47·333	−0·139	−23 7 12·86	+5·57	*y*	5
		47·221		11·61		*x*	5
14·72505	−·00859	9 30 29·332	−0·034	−24 26 0·83	+5·79	*z*	5
		29·701		25 54·95		α	5
17·70355	−·00861	9 23 55·545	−0·049	−25 21 9·42	+5·78	β	5
		γ+3 42·039		γ−0 47·96		γ	5
		δ+1 41·183		δ−4 37·71		δ	5
		ε−1 4·832		ε+8 57·74		ε	5
20·72437	−·00863	9 16 49·435	+0·008	−26 14 5·26	+5·81	ζ	5
		49·615		4·83		η	5
		49·473		5·49		θ	5
		ι−4 4·233		ι−10 42·90		ι	5
23·73969	−·00865	9 9 17·401	+0·057	−27 3 5·85	+5·78	κ	2
		λ+0 23·305		λ−1 12·02		λ	2
26·70023	−·00868	9 1 30·494	+0·014	−27 47 36·82	+5·80	μ	6
		30·818		37·44		ν	6
		ξ−1 16·764		ξ−4 9·79		ξ	6
		ο−2 36·325		ο−6 19·48		ο	6
		π−5 18·977		π+2 30·53		π	6

Assumed Mean Places for 1882·0 *of Stars compared with the Great Comet* (b) 1882, *with Reductions to Apparent Place for the Night of Observation.*

	Right Ascension.	Reduction.	Declination.	Reduction.	Authority.
	h m s	s	° ′ ″	″	
a	10 3 37·016	+2·572	−17 33 21·66	−9·61	Lalande 19797.
b	5 33·145	+2·567	−17 24 41·42	−9·72	Argelander 279′–55ⁿ.
c	3 32	+2·571	−17 36 28	−9·59	
d	4 55·923	+2·591	−18 1 18·34	−9·61	Lalande 19834.
e	2 43	+2·599	−17 50 36	−9·57	
f	3 1	+2·598	−17 55 39	−9·57	
g	9 58 42·906	+2·687	−18 52 9·82	−9·41	Argelander 356–41.
h	58 50·485	+2·687	−18 50 23·07	−9·41	„ 356–42.
i	55 45	+2·724	−19 6 8	−9·32	

	Right Ascension.	Reduction.	Declination.	Reduction.	Authority.
	h m s	s	° ′ ″	″	
j	9 56 36	+2·720	−19 11 39	−9·33	
k	53 45·720	+2·783	−19 47 32·55	−9·11	Lalande 19559, 19561.
l	57 3·070	+2·771	−19 51 13·48	−9·35	„ 19641.
m	57 20·629	+2·795	−20 15 42·58	−9·34	Argelander 356–39.
n	57 40·312	+2·793	−20 21 35·36	−9·33	„ 356–40.
o	56 9·622	+2·799	−20 23 53·12	−9·28	„ 356–37.
p	48 13	+2·910	−21 17 26	−9·07	
q	43 20·811	+2·925	−21 28 15·58	−8·83	Lalande 19275.
r	47 27·325	+2·950	−21 23 9·30	−9·02	Argelander 283–25.
s	43 8·002	+2·980	−22 7 50·76	−8·88	Lalande 19269.
t	40 51·567	+2·988	−22 6 33·66	−8·80	Argelander 283–16.
u	45 36·817	+2·999	−22 27 56·66	−9·00	„ 283–23.
v	45 47·598	+2·999	−22 24 37·63	−9·03	„ 283–24.
w	39 12·979	+3·051	−22 49 9·58	−8·81	„ 283–14.
x	39 31·702	+3·048	−22 56 31·70	−8·78	„ 283–13.
y	39 15·365	+3·079	−23 1 56·28	−8·88	„ 283–12.
z	30 28·699	+3·228	−24 19 36·54	−8·78	„ 400–138.
α	31 14·925	+3·227	−24 10 37·77	−8·85	„ 281–3 and 400–137.
β	16 16·144	+3·363	−25 27 49·35	−8·43	Melbourne Cat. 1870, 468 } Mean.
β	16 16·134	+3·363	−25 27 49·77	−8·43	Cape Cat. 1880, 4996 }
γ	20 11	+3·351	−25 20 16	−8·61	
δ	22 12	+3·345	−25 16 20	−8·71	
ε	24 57	+3·332	−25 29 58	−8·74	
ζ	21 25·600	+3·439	−26 3 57·46	−9·01	Argelander 290–129.
η	24 26·772	+3·428	−26 4 36·37	−9·11	Melbourne Cat. 1870, 474.
θ	24 40·192	+3·428	−26 4 23·14	−9·11	Melbourne Cat. 1870, 476.
ι	20 50	+3·441	−26 3 13	−8·99	
κ	5 57·944	+3·578	−26 57 34·26	−8·79	Argelander 352–179.
λ	8 51	+3·568	−27 1 45	−8·89	
μ	5 27·425	+3·668	−27 42 9·78	−9·22	Argelander 352–178.
ν	8 36·369	+3·657	−27 49 6·43	−9·29	„ 352–184.
ξ	2 44	+3·676	−27 43 18	−9·11	
ο	4 3	+3·673	−27 41 8	−9·17	
π	6 46	+3·663	−27 49 58	−9·23	

Mean Places for 1882·0 from other sources, not used in deducing the Comet's place.

	h m s	s	° ′ ″	″	
g	9 58 42·248	+2·687	−18 52 12·35	−9·41	Lalande 19696.
h	58 50·307	+2·687	−18 50 23·72	−9·41	„ 19699.
t	40 51·344	+2·988	−22 6 28·81	−8·80	„ 19209.
u	45 36·905	+2·999	−22 27 53·31	−9·00	„ 19338.
w	39 13·433	+3·051	−22 49 10·45	−8·81	„ 19153.
	39 31·886	+3·048	−22 56 30·72	−8·78	„ 19164.
y	39 14·234	+3·079	−23 1 54·37	−8·88	„ 19154.

The observations were made and reduced by Mr. Graham.

On Photographs of the Great Comet (b) 1882. By David Gill, LL.D., Her Majesty's Astronomer at the Cape of Good Hope.

I have obtained photographs of the Great Comet of this year by attaching to the declination-axis-counterpoise of the 6-in. Grubb Equatorial an ordinary camera with a rapid portrait-lens by Dallmeyer of about 2½ inches aperture and 11 inches focal length.

The attachment was such that any motion given to the telescope tube was common also to the camera. During exposure the image of the comet's nucleus was kept upon the intersection of two webs of the filar micrometer by means of clockwork, aided by the fine slow motions in R.A. and Declination.

In Photograph 3 (which is the most perfectly focussed) the photographic images of the neighbouring stars are elongated in the direction of the comet's motion.

I am indebted to Mr. E. H. Allis, Photographer, Mowbray, for the loan of the camera in question, and for his assistance in the work. I was too much occupied with the observations of *Victoria* and *Sappho* to be able to turn my attention to photographing the comet till after Oct. 11, when the *Sappho* observations were finished.

The successful photographs that have been obtained are:—

No. 1. 1882 Oct. 19^{d} 15^{h} 45^{m} Cape M.T., Exposure 30^{m}.
No. 2. 1882 Oct. 20^{d} 15^{h} 30^{m} „ „ 1^{h}.
No. 3. 1882 Oct. 21^{d} 15^{h} 40^{m} „ „ 40^{m}.

Of these photographs paper copies are enclosed. After Oct. 21 the work was interrupted by moonlight, but it will be resumed at next new Moon.

With more sensitive plates and longer exposure I do not doubt that photographs may be obtained for some time to come.

There is a very marked difference between the photographic magnitude and the apparent magnitude of stars. There is also an apparent difference in the photographic magnitudes caused by errors in the correction of the spherical aberration of the lens,

giving longer disks in one part of the field than in another. But there is no real difficulty in identifying all the photographed stars.

Photograph No. 2, particularly in the original negative, shows the curious envelope extending 2° beyond the head. It is less distinctly seen in Photograph 3.

This preliminary communication will afterwards be supplemented.

Royal Observatory,
Cape of Good Hope:
1882, *Oct.* 31.

[Since the foregoing paper was received, Mr. Gill has forwarded to the Society three additional photographs of which the following are the particulars:—

No. 4.	1882 Nov.	$7^d\ 14^h\ 42^m$	Cape M.T., Exposure	$1^h\ 40^m$.
No. 5.	1882 Nov.	$13^d\ 14^h\ 0^m$	„ „	$1^h\ 20^m$.
No. 6.	1882 Nov.	$14^d\ 14^h\ 15^m$	„ „	$2^h\ 20^m$.]

Observations of the Great Comet (b) 1882, *made at Auckland, New Zealand.* By J. T. Stevenson.

(*Extract from a letter to the Rev. T. W. Webb.*)

. . . I have the pleasure of now sending you a few particulars of the beautiful comet at present visible here. . . . I will begin with the head, which to me appeared at first nearly equal to a first-magnitude star, and, I may add, was seen in New Zealand in broad daylight when it was in perihelion.

I find that when viewed in the telescope the head appears just like a double star, when the power is not sufficient to separate the disks; of course I do not mean that the head is double, but it is elongated in an east and west direction, which is at present the direction of the comet's motion. On the 5th instant and once before I saw a *minute* point in the nucleus which glowed brightly.

The Dark Space behind the Head.—I notice what seems rather remarkable in the dark space: namely, the fact that whereas I am almost positive in other comets which I have seen that the dark space was broad, yet in this, the most brilliant one seen for many years, this space is very narrow. I may mention also that the head appeared slightly inclined towards the axis of the tail, and that the dark space is not directly behind, but as if the head were a little north of the axis of this space in the tail.

The Tail.—This is grand in the extreme; I have never seen anything equal to it. At the extremity it is at least several times broader than the Moon's apparent diameter. I can see the faintest stars visible through even the thickest portion of it. With a small glass I can trace plainly the dark space running up through it from the head; and here I notice another peculiarity—namely, that this space is not central in the tail, but divides it into two unequal portions, the northern of which is much broader than the other. Up to October 6, on the occasions

on which I observed, there was also seen a fainter tail extending from the north part of the head and reaching as far as the brighter one; with the naked eye the northern part of the tail was seen to be *darker* than the other parts, and it is this part which I consider the second tail. I was particular in trying to trace it right down to the head, as I had a suspicion that it had a square-shouldered aspect (I might call it) where it joined the nucleus; but of this I was not sure.

Yesterday morning, however (Oct. 6), on looking at the comet, which was then very low, I was surprised to find that the fainter portion of the tail had extended itself on both sides of the head and appeared as a second tail *pointing towards the Sun.* I traced it fully two degrees beyond the nucleus—that is, in a direction contrary to the brighter tail.

I am aware that the nuclei of some comets are of considerable extent sometimes, but I do not think what I saw on this occasion could be considered any part of the nucleus. I may state that the finder of the telescope showed this appearance also, while in the telescope itself the region in front of the nucleus was misty and ill-defined. I had not noted this mistiness on any former occasion. I noticed particularly that this fainter tail made a small angle with the direction of the brighter one. There are only two ways in which I can account for this appearance not being noted before: either that the fainter tail is really expanding, or else that the waning Moon, or else a particularly fine morning, enabled greater detail to be visible.

Oct. 10.—I have longed to get another view of comet before the mail leaves, and after two days cloudy weather I succeeded this morning.

I found that the faint tail had now extended itself sunwards for (I think) more than four degrees. I again suspected that it was not quite parallel with brighter one, but am not sure on this point. I have noticed all along the bright tail is longer on its southern side, and also that the extremity of tail has a dark space which splits that portion nearly in two. . . .

The observations were made with a $6\frac{1}{2}$ Reflector by Calver.

Postscript by the Rev. T. W. Webb.

In addition to the corroboration which Mr. Gill has afforded with regard to this remarkable phenomenon, I beg permission to mention that I have since been informed by a gentleman named Jackson, at Constantinople, that on the 2nd or 3rd, as he believes, of October, he saw the same appearance with a 4-in. object-glass as "very faint parallel rays of light stretching from the head of the comet towards the Sun;" and that at a still later date I have been favoured with a communication from Professor Schiaparelli, in which he mentions this and other still more remarkable peculiarities as observed especially by himself, and in part by Schmidt, at Athens.

Hardwick Vicarage:
1882, *Nov.* 18.

Observations of the Great Comet (b) 1882, *made at the O'Gyalla Observatory, Hungary.* By Dr. N. de Konkoly.

The comet, when first observed, had already lost much of its former brightness, and until November 1 all observation was prevented by continuous clouds and rainy weather. Since that time I have seen it only once between clouds, but observations then were too difficult to make. Our moist climate, together with a considerable diminution in the brightness of the comet, gives but little hope for further observations.

The observations were made on November 1, 17^h Mean Time, with the 6" Refractor of Merz, the view from the $9\frac{1}{2}$-in. Merz Refractor being limited by the dome of the 6-in. and by trees.

In the telescope the head of the comet was very remarkable. Its oblong nucleus sharply defined towards the tail, showed two brighter points of light. The nucleus appeared of a pretty strong yellow colour, while the coma was a little greenish. The tail was considerably curved upwards, and the edge turned towards the horizon was much brighter and better defined than the other. A radiation from the nucleus, which large comets generally show, did not exist, and the whole head of the comet appeared like a candlelight seen through fog. The edges, even of the nucleus, were exceedingly indefinite. The spectrum was compared with that of a Bunsen gas flame according to the method of Professor Vogel. The nucleus had a very intense continuous spectrum, the red end of which was very bright. I could not see any sodium line. The coma showed a tolerably bright comet spectrum, characterised by the hydrocarbon bands. Later in the morning the view being more open from the northern dome, the observations were made with the large refractor. I measured three of the bands, intended to measure a fourth, and suspected a fifth towards the red. Taking the intensity of the brightest band in the yellow-green as unity, the ratio of the intensities of the others is: 0·1 (?), 0·7, 1·0, 0·2, and 0·4. The first is the suspected band in the red. The following are the results expressed in wave-lengths.

			Mm.
I.	...	...	—
II.	...	...	562·0
III.	...	...	514·7
IV.	...	...	502·6 (?)
V.	...	...	472·

All lines seemed much thickened in the middle, and better defined toward the less refrangible end of the spectrum, while fainter toward the violet. The measurements of the spectrum of the Bunsen flame gave the following results:—

	Edge.	Maximum.
I.	610·0	596·2
II.	560·2	556·9
III.	514·7	513·1
IV.	472·2	469·9
V.	—	431·4

The little discordance between the two spectra perhaps may be explained by the small dispersion of the apparatus employed.

O'Gyalla Observatory:
1882, *Nov.* 12.

Observations of the Great Comet (b) 1882, *made on board H.M.S. "Triumph."* By the Rev. Joseph Reed.

This interesting object was first seen and reported on Sunday, September 10. On Monday rain and clouds prevented its being seen; but on the 12th and 13th I was fortunately able to take observations to determine its R.A. and Declination, but these results are approximate, the sextant and compass being the only instruments available. Each morning, owing to banks of cloud and the increasing twilight, the comet was visible for only a few minutes before sunrise; the twilight prevented my determining the length of the tail, but it appeared to extend through an arc of two or two and a half degrees. The whole of the coma is very brilliant, the nucleus surrounded by a still brighter ring; the tail was not curved.

1882, *September* 12.

Latitude	° 11	′ 12	″ 0	N.
Longitude	24	40	0	W.
Ship's Time of Observation ...	h 5	m 22	s 18	A.M.
True Altitude of Nucleus ...	° 8	′ 28	″ 30	
R.A. of Comet	h 11	m 25	s 3	
Declination of Comet	° 4	′ 10	″ 23	S.

1882, *September* 13.

Latitude	° 13	′ 54	′ 0	N.
Longitude	24	20	0	W.
Ship's Time of Observation ...	h 5	m 11	s 20	A.M.
True Altitude of Nucleus ...	° 4	14	47	
R.A. of Comet	h 10	m 58	s 24	
Declination of Comet	° 0	′ 54	′ 58	

Sextant Observations of the Great Comet (b) 1882. By T. P. Parry, 4th Officer, s.s. *Almora.*

(*Communicated by Capt. H. Toynbee, R.N.*)

The observations were made in the Red Sea, off the *Dædalus* Light Ship, on October 14, 1882, at 4 A.M., app. time.

		°	′
Altitude of Comet	... ...	5	0
Distance from Regulus	... ...	25	25
„ Sirius	... ...	53	20
„ Procyon	... ...	46	40
„ Canopus	... ...	61	35

Observations of Comet Wells, 1882, *at Windsor, New South Wales.* By John Tebbutt.

Although this comet was detected here as early as June 15, the strong twilight prevented my seeing any stars of comparison, and it was not till the 19th that micrometer observations could be commenced. The long-continued clear weather enabled me to secure a large number of positions with the 4½-in. Equatorial, which I trust may prove of service in the definitive determination of the orbit. The positions from June 19 to July 6 inclusive were obtained with the filar micrometer. The early set of comparisons on July 7 were also made with the filar micrometer, but the later set with a square bar micrometer. All the positions subsequent to the 7th depend on the square bar micrometer. During the early part of July the comet would scarcely bear field illumination. The differential measures are corrected where necessary for refraction, and those dependent on the square bar have had corrections applied for the comet's proper motion, which was rather rapid in Right Ascension. I have added the log. factors for parallax, p and q being the usual corrections in time and arc respectively, and P the comet's equatorial horizontal parallax. I have selected the best authorities available for the stars of comparison. The mean places have been brought up by means of the precessions calculated for the mean dates between the epochs of the respective catalogues and 1882, by employing Peters's elements; but proper motion has not been applied in any case. On the evenings of July 1 and 2 I noted stars Nos. 19 and 20 to be respectively of the 5½ and 6th magnitude, but was not aware that the latter was the well-known variable *R. Leonis* till I came to the reductions for the identification of the stars of comparison. It could not have been far from its maximum.

Apparent Places of Comet Wells, 1882.

Windsor Mean Time 1882.	d	h	m	s	R.A. h	m	s	Log $\frac{p}{P}$ +	N.P.D. °	′	″	Log $\frac{q}{P}$ +	No. of Comps.	Comp. Star.
June	19	5	38	7	7	22	19.31	8.7039	74	44	2.5	9.8036	6	1
	19	6	1	56	7	22	32.79	8.7255	74	44	15.4	9.7894	10	1
	20	6	14	4	7	35	54.20	8.7272	74	57	25.3	9.7872	4	2
	21	6	21	11	7	48	43.47	8.7253	75	10	52.0	9.7879	3	3
	21	6	21	11	7	48	43.38	8.7253					3	4
	22	6	1	2	8	0	50.80	8.6986	75	25	17.7	9.8035	10	5
	22	6	1	36	8	0	51.37	8.6992					8	6
	22	6	28	18	*	+1	33.41	8.7238	*	+0	34.1	9.7881	4	7
	23	6	34	10	8	12	55.92	8.7217	75	40	35.1	9.7888	6	8
	24	6	21	35	8	24	9.75	8.7030					6	9
	24	6	26	3	8	24	11.26	8.7074	75	56	5.2	9.7969	8	10
	25	6	35	43	8	35	6.31	8.7095	76	12	19.5	9.7946	5	11
	26	6	40	54	8	45	30.87	8.7078	76	28	49.7	9.7945	8	12
	27	6	14	58	8	55	15.82	8.6714	76	45	20.4	9.8093	10	13
	27	6	46	21	8	55	28.27	8.7068	76	45	42.0	9.7940	10	13
	28	6	24	10	*	+0	24.99	8.6754	*	+4	25.2	9.8064	5	14
	29	6	26	58	9	13	50.98	8.6721	77	19	42.8	9.8064	15	15
	30	7	20	34	9	22	47.16	8.7216	77	37	33.5	9.7819	3	16
July	1	6	17	35	*	+0	37.36	8.6453	*	−8	36.9	9.8116	9	17
	1	6	53	8	*	+0	48.99	8.6917	*	−8	9.2	9.7964	4	17
	1	6	53	8	9	30	49.78	8.6917	77	54	23.4	9.7964	4	18
	1	6	53	8	9	30	50.25	8.6917	77	54	28.5	9.7964	4	19
	2	6	55	3	9	38	40.72	8.6890	78	11	37.5	9.7963	5	20
	3	6	45	30	*	−1	2.20	8.6729	*	−0	27.2	9.8009	6	21
	3	6	45	30	9	46	6.46	8.6729	78	28	24.6	9.8009	6	22
	4	6	51	54	9	53	16.73	8.6765	78	45	8.9	9.7984	8	23
	5	6	52	23	10	0	5.37	8.6731	79	1	42.8	9.7981	4	23
	5	6	57	55	*	+7	55.68	8.6799	*	+0	48.7	9.7960	3	24
	6	7	0	10	10	6	38.60	8.6791	79	18	12.4	9.7950	1	25
	7	7	18	41	10	12	54.83	8.6968	79	34	22.3	9.7874	5	26
	7	7	46	36	10	13	3.49	8.7212	79	34	40.7	9.7754	9	26
	9	7	21	50	10	24	35.07	8.6955	80	5	33.4	9.7857	15	27
	12	7	11	11	10	40	14.03	8.6784	80	49	46.2	9.7881	8	28
	13	7	15	41	10	45	4.18	8.6824	81	4	2.3	9.7859	3	29
	13	7	15	41	10	45	4.01	8.6824	81	4	3.2	9.7859	3	30
	13	7	15	41	*	−1	13.57	8.6824	*	−5	50.7	9.7859	3	31

Windsor Mean Time 1882.					R.A.			Log $\frac{p}{P}$	N.P.D.			Log $\frac{q}{P}$	No. of Comps.	Comp. Star.
	d	h	m	s	h	m	s	+	°	′	″	+		
July	14	7	6	10	✱	−1	42·42	8·6698	✱	−2	46·9	9·7884	3	32
	17	7	21	45	11	2	36·83	8·6862	81	58	5·7	9·7806	10	33
	18	7	28	47	11	6	37·08	8·6934	82	10	50·5	9·7775	9	34
	19	6	56	26	11	10	23·61	8·6543	82	22	55·0	9·7863	2	35
	19	7	7	39	✱	−1	7·75	8·6692	✱	+0	30·2	9·7829	5	36
	19	7	12	26	✱	+1	16·84	8·6751	✱	+3	43·4	9·7817	4	37
	22	7	12	16	✱	−1	25·68	8·6756	✱	−4	47·0	9·7786	5	38
	22	7	13	52	11	21	15·36	8·6774	82	59	11·8	9·7782	6	39
	22	7	13	52	11	21	15·35	8·6774	82	59	11·1	9·7782	6	40
	23	7	28	16	11	24	40·63	8·6936	83	10	47·8	9·7731	6	41
	24	7	17	12	11	27	56·02	8·6823	83	21	59·3	9·7752	7	42
	25	7	17	23	11	31	6·92	8·6832	83	33	3·3	9·7740	7	43

Mean Places of the Comparison Stars for 1882·0 with the Reductions to the Apparent Places for the Dates of Observation.

Comp. Star.	Mean R.A.			Reduction. +	Mean N.P.D.			Reduction. +	Authority for Star's Mean Place.
	h	m	s	s	°	′	″	″	
1	7	22	4·34	1·25	74	38	56·9	8·6	Lalande, 14515.
2	7	43	52·03	1·29	74	51	36·0	9·2	„ 15246.
3	8	3	29·19	1·33	75	8	19·2	9·8	„ 15939.
4	8	4	21·11	1·32	75	1	20·4	9·9	„ 15968 and 15970.
5	8	1	26·21	1·32	75	18	28·3	9·8	Wash. Cat. 1860, 3294.
6	8	1	7·07	1·32	75	17	55·8	9·8	„ 3292.
7	7	59	30	1·32	75	25		9·7	Star 8 mag., Approx. Pos. by Equatorial.
8	8	5	46·06	1·33	75	38	41·8	9·9	Gr. 7 Yr. Cat. 1864, 1019; Gr. 9 Yr. Cat. 1872, 801; Bruxelles Cat. 1876, 378.
9	8	27	45·53	1·38	75	54	41·6	10·5	Weisse, 8ʰ, 667.
10	8	29	37·45	1·38	75	48	58·1	10·5	Bruxelles Cat. 1873, 1351, and 1876, 405.
11	8	35	47·00	1·39	76	12	14·4	10·7	Lalande, 17130.
12	8	52	57·57	1·44	76	28	7·0	11·0	Schjellerup, 1865, 3300; Bruxelles Cat. 1873, 1423; and Rad. Obs. 1874, 520.
13	8	54	22·31	1·44	76	57	58·4	11·2	Schjellerup, 1865, 3310.
14	9	4	26	1·46	77	0		11·3	Star 8 mag., Approx. Pos. by Equatorial.
15	9	14	52·34	1·49	77	15	24·7	11·5	Weisse, 9ʰ, 270.
16	9	24	41·68	1·52	77	37	26·1	11·7	„ 492.
17	9	30	0	1·53	78	2		11·8	Star 7½ mag., Approx. Pos. by Equatorial.
18	9	34	48·41	1·55	77	53	58·0	11·8	Schjellerup, 1865, 3558.

Comp. Star.	Mean R.A.	Reduction. +	Mean N.P.D.	Reduction. +	Authority for Star's Mean Place.
	h m s	s	° ′ ″	″	
19	9 41 5·42	1·57	77 53 12·6	11·9	Radcliffe Obs. 1858, 657.
20	9 41 12·68	1·56	78 1 28·0	11·9	Wash. Cat. 1860, 4075; Gr. 7 Yr. Cat. 1864, 1201, and Wash. Obs. 1872, 216.
21	9 47 6	1·58	78 29	12·0	Star 8½ mag., Approx. Pos. by Equatorial.
22	9 52 20·12	1·60	78 28 40·5	12·0	Lalande, 19515.
23	9 52 27·28	1·59	78 58 41·9	12·1	Lalande, 19517.
,,	,,	1·59	,,	12·1	
24	9 52 11	1·59	79 1	12·1	Star 8½ mag., Approx. Pos. by Equatorial.
25	10 1 38·58	1·62	79 25 27·6	12·2	Wash Cat. 1860, 4218; Gr. 7 Yr. Cat. 1864, 1229, and Gr. 9 Yr. Cat. 1872, 956.
26	10 13 12·56	1·65	79 29 15·1	12·2	Lalande, 20021.
27	10 26 35·87	1·69	80 5 13·3	12·3	Nautical Almanac, 1882.
28	10 35 12·31	1·71	80 49 12·2	12·4	Lalande, 20630 and 20631.
29	10 42 34·07	1·73	81 9 21·7	12·4	Weisse, 10ʰ, 732.
30	10 41 12·43	1·72	81 6 55·5	12·4	,, 704.
31	10 46 17	1·74	81 10	12·4	Star 8 mag., Approx. Pos. by Equatorial.
32	10 51 22	1·76	81 20	12·3	Star 9 mag., Approx. Pos. by Equatorial.
33	10 58 55·76	1·77	82 1 36·2	12·3	Nautical Almanac, 1882.
34	11 0 2·16	1·77	82 13 31·4	12·3	Gr. Obs. 1859, 327; Rad. Obs. 1873, 560, and 1874, 634.
35	11 0 0·28	1·76	82 19 31·4	12·3	Lalande, 21261.
36	11 11 32	1·81	82 22	12·2	Star 9½ mag., Approx. Pos. by Equatorial.
37	11 9 7	1·80	82 19	12·2	Star 8½ mag., Approx. Pos. by Equatorial.
38	11 22 39	1·84	83 4	12·1	Star 9½ mag., Approx. Pos. by Equatorial.
39	11 28 52·73	1·86	83 4 9·6	12·0	Schjellerup, 1865, 4185.
40	11 31 13·31	1·87	83 4 38·5	12·0	Schjellerup, 1865, 4198; Rad. Obs. 1874, 675, and Bruxelles Cat. 1873, 1800; 1874, 959; and 1876, 661.
41	11 30 30·41	1·86	83 14 12·2	12·0	Wash. Cat. 1860, 4847; Schjell. 1865, 4196 and 4197; Bruxelles Cat. 1873, 1795, and 1875, 314.
42	11 32 59·37	1·87	83 17 2·7	11·9	Wash. Cat. 1860, 4872; Schjell. 1865, 4202 & 4203; Bruxelles Cat. 1874, 965; 1875, 318; and 1876, 666.
43	11 32 56·56	1·86	83 33 32·5	12·0	Lalande, 22079.

Postscript.

I may add that the comet (Comet *b*, 1882), two positions of which I forwarded to you by a previous mail, has since presented a magnificent spectacle in our morning sky. Between 9 and 10 o'clock on the morning of Sept. 17 I detected it without a telescope. It was then about four degrees west of the Sun and moving fast towards that luminary. The head and the tail for about a third of a degree were well seen. At 11^h 35^m A.M. on the following day I could again plainly distinguish it without optical aid simply by screening the eye from the Sun's direct rays. It was then less than a degree west of the Sun's western limb, and moving west, having obviously shortly before passed its perihelion. In a communication which appeared in the *Herald* of Sept. 19 I pointed out that if we assumed 6^h a.m. on the 18th as the time of perihelion passage of the great comets of 1843 and 1880, their apparent places from the 8th to the 18th would be nearly represented by those occupied by the visible comet. My conclusion was that the path of our present visitor was very similar to those described by the comets just referred to, and my suspicions have been confirmed by an approximate orbit completed at the Melbourne Observatory. Although the comet has been such a grand object in our morning sky for some time past, I have been unable till recently to find comparison stars in consequence of haze and bright twilight. As it possesses more than ordinary interest, I will endeavour to secure as many positions as possible.

Observatory, Windsor, N. S. Wales:
1882, *Oct.* 4.

Observation of the Transit of Venus, 1882, *Dec.* 6, *made at Glasgow Observatory.* By Professor R. Grant, M.A., F.R.S.

The ingress of *Venus* upon the Sun's disk on December 6 was well seen at the Glasgow Observatory. The sky during the early part of the day was somewhat overcast, but about one o'clock P.M. the day cleared up, and the Sun continued thereafter to shine with unclouded brilliancy until it descended beneath the horizon. My observation of the phenomenon was made with the large Equatorial of the Observatory, the object-glass of which, nine inches aperture, was reduced by a diaphragm to five and a half inches. The magnifying power used was 120. At 2^h 3^m 2^s Greenwich Mean Time a very slight indentation in the Sun's limb, indicative of the external contact of the planet with the Sun, was perceptible. The planet was now seen advancing

gradually over the Sun's limb, and about 2^h 19^m I began to think that the internal contact would soon occur. In this respect, however, I was deceived, for at 2^h 19^m 55^s the dark ligament, respecting which I had read and heard so much, was now distinctly seen. As the planet proceeded in its course the ligament became more and more elongated, and also more attenuated towards the Sun's limb, until finally, at 2^h 22^m 32^s, the rupture of the ligament occurred, and the Sun's light immediately flowed round, leaving a sensible margin of light between the planet and the Sun's limb. I remarked that immediately previous to its disappearance, the dark ligament exhibited a rapid vibratory movement. This, however, lasted only two or three seconds. I am of opinion that the rupture of the ligament indicated the instant of the internal contact of the planet with the Sun.

During the observation I saw no trace of an atmosphere about the planet, and I similarly failed to discover any indication of the existence of a satellite revolving round it.

In consequence of the low altitude of the Sun, it presented a tremulous aspect at its limb during the time that the phenomenon was visible, and the same remark is applicable to the edge of the planet's disk. I am inclined to think, however, that the observation on the whole was made under favourable circumstances.

The external contact of the planet with the Sun undoubtedly occurred a few seconds earlier than the time above stated, but not, I think, earlier than between three and five seconds; and in this opinion I am supported by an experienced friend, Mr. Thomas Davison, who was with me during the observation.

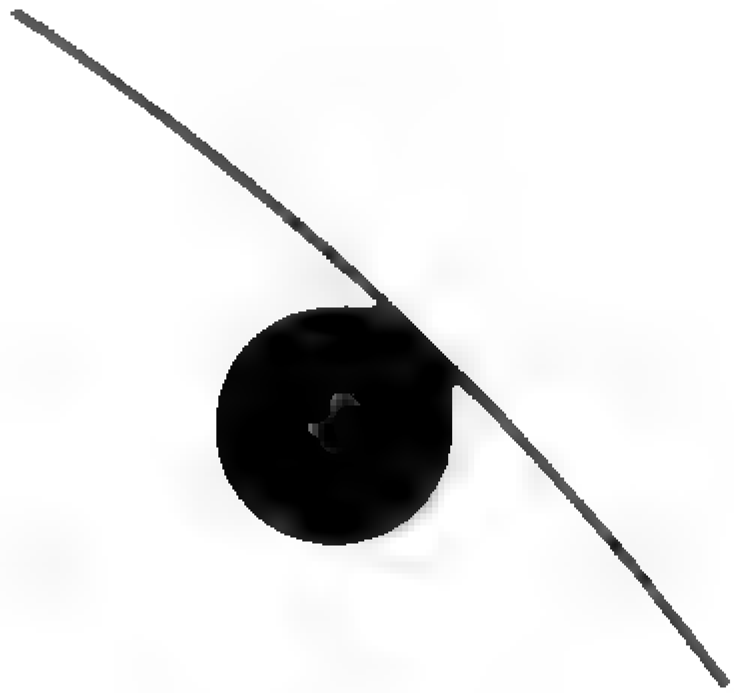
Sir William Thomson having come to the Observatory for the purpose of seeing the planet on the Sun through the large telescope, a small Dollond of 3 inches aperture was placed at his disposal, and with this instrument, having a magnifying power of 60, he noted the internal contact to have occurred at 2^h 22^m 12^s. No trace of a dark ligament was perceived by him.

The Observatory, Glasgow:
1882, *Dec.* 7.

Observation of the Transit of Venus, 1882, December 6, made at Crowborough, Sussex. By C. Leeson Prince.

The morning of Dec. 6 looked as unpromising for seeing the very interesting phenomenon which was about to happen as could well be imagined. The temperature at 9 a.m. was only 31°; the barometer was low and the wind N. Added to this the sky was so densely overcast that one of Crookes's radiometers scarcely performed one revolution per minute, and slight showers of hail, sleet, and snow were falling at intervals until noon. The first gleam of sunshine appeared at $1^h\ 40^m$, but two minutes afterwards the Sun was again obscured till $1^h\ 55^m$ by a large mass of cumulus cloud lying above some drifting scud. The Sun was obscured till $2^h\ 12^m$, when, through a break in this cloud, the Sun shone out with *Venus* having passed half her diameter upon his disk. A minute afterwards the Sun was again obscured till $2^h\ 16^m$ when the heavier clouds passed away, and I had no further serious interruption from them during the remainder of the afternoon. On account of my elevation above sea-level (825 feet) I was favoured by being situated just above some drifting scud, a dense stratum of which was passing below me; and when, now and then, a thin portion of this passed before the Sun, it rather tended to improve the definition than otherwise. From $2^h\ 16^m$, therefore, I watched very attentively the near approach of internal contact. At $2^h\ 17^m$ I first noticed the visibility of that portion of the planet still outside the Sun's disk, and which appeared to be illuminated by a brilliant silver line of light, which most distinctly marked the limb of that portion of the planet, and which was doubtless produced by the refraction of sunlight passing through the planet's atmosphere. The effect was very beautiful. At $2^h\ 22^m\ 7^s$ I noticed that the planet's disk became slightly distorted, and then apparently elongated upon the Sun's limb, so that I became somewhat perplexed how I should determine the instant of contact. This feature continued till $2^h\ 22^m\ 15^s$, when I observed the following. This shadow, or ligament, or whatever it was, *suddenly* left the Sun's limb in something less than a second of time, and gathering up towards the planet was no longer visible. It did not lengthen itself, or become narrower, or form a black drop towards the Sun, but merely disappeared, as I have before said, close to the planet. When this had happened I found that internal contact was over, and that there was a clear line of separation between the two limbs. I consider, therefore, that the above time of $2^h\ 22^m\ 15^s$ was *late*, and that actual contact had been over 3^s or 4^s, which would bring the time of contact to correspond very closely indeed with the theoretical time of contact for my Observatory, which was kindly sent me by Dr. Hind on the 3rd inst.—viz.

$2^h\ 22^m\ 11^s$. The following is a sketch of the phenomenon about $2^h\ 22^m\ 12^s$:—



I next directed my attention to the general appearance of *Venus*, now fully upon the Sun's disk, and I at once perceived that a halo of yellowish light surrounded her—it was not a *ring*, as in the case of *Mercury*, but a very diffused light, and constantly varying in breadth—now here, now there. As the planet advanced, this halo became much fainter, until at 3 p.m. it was no longer visible. There was no appearance of a satellite. The planet's surface was uniformly black, without the slightest speck of light visible anywhere upon it. At $3^h\ 30^m$ I went to my upper Observatory with the intention of watching the phenomenon down to the horizon with my 3-in. Wray Telescope. When within five degrees of the visible horizon the planet became decidedly elongated, and just at last almost linear. It was a splendid sunset—the Sun, shorn of rays and of a beautiful carmine colour, lit up some surrounding clouds with many gradations of the same tint, the effect of which was visible some time after the disappearance of the magnificent orb with its planet behind a large mass of cumulo-stratus cloud lying over the sea. It was a sight not to be forgotten by those who witnessed it. I did not take any micrometrical measures or photographs, having quite decided upon merely watching what might happen, and recording what was noteworthy.

I made use of my Tulley Equatorial, of 6·8 inches aperture and twelve feet focal length, to which I applied a Dawes' solar eyepiece with a power of 100.

The Observatory, Crowborough:
1882, Dec. 7.

Observation of the Transit of Venus, 1882, December 6. By W. E. Cooper.

I had a very good observation of the transit of *Venus* of December 6 with my 9-in. silver-on-glass Reflector by Calver; power used about 150. The definition was good, the rice grains being *very* distinctly visible a short time before the transit.

		°	′	″
Latitude N.	... ...	52	14	+
Longitude W.	... ...	2	12	45

Clock 11^s fast.

Owing to clouds the first contact not seen.

	h m s	Corrected Time = -11^s. h m s
Dark limb of *Venus* first seen	2 2 45	2 2 34
Not half on limb of Sun	2 10 30	—
Half on limb of Sun	2 11 30	2 11 19
More than half	2 11 46	—
Venus wholly visible	2 14 30	2 14 19
Internal contact not taken place	2 20 0	—
The last appearance of any well marked discontinuity in the illumination in the limb of the Sun near point of contact	2 21 55	2 21 44
Internal contact over	2 22 4	—

The Mount, Worcester:
1882, *Dec.* 7.

Ephemeris of the Satellites of Uranus, 1883. By A. Marth.

The major and minor semiaxes *a* and *b* of the apparent ellipses described by the satellites, the angle of position P of the minor axes in the direction of superior conjunction, and the latitude of the Earth above the assumed plane of the orbits, are the following:—

Greenwich Noon.	*Ariel.* a_1	b_1	*Umbriel.* a_2	b_2	*Titania.* a_3	b_3	*Oberon.* a_4	b_4	P.	Lat. of Earth.
1883.	″	″	″	″	″	″	″	″	°	″
Jan. 9	14·83	+1·91	29·65	+2·66	33·88	+4·37	45·31	+5·84	285·52	+7·40
19	14·95	1·89	20·83	2·63	34·16	4·32	45·68	5·77	·51	7·26
29	15·06	1·84	20·98	2·56	34·42	4·21	46·02	5·63	·51	7·02
Feb. 8	15·15	1·77	21·11	2·47	34·63	4·05	46·31	5·42	·49	6·72
18	15·23	1·68	21·21	2·35	34·79	3·85	46·53	5·15	·48	6·35
28	15·27	1·58	21·28	2·20	34·90	3·62	46·67	4·84	·46	5·95
Mar. 10	15·29	1·47	21·31	2·05	34·95	3·36	46·73	4·50	·44	5·52
20	15·29	1·36	21·30	1·89	34·93	3·10	46·71	4·15	285·41	5·09
30	15·25	1·24	21·25	1·73	34·85	2·84	46·61	3·80	·39	4·68
Apr. 9	15·20	1·14	21·17	1·58	34·72	2·60	46·43	3·48	·36	4·29
19	15·11	1·04	21·06	1·45	34·54	2·38	46·19	3·19	·34	3·96
29	15·02	0·97	20·92	1·35	34·31	2·21	45·88	2·95	·32	3·69
May 9	14·90	0·91	20·76	1·27	34·05	2·08	45·53	2·78	·31	3·49
19	14·78	0·87	20·58	1·21	33·76	1·99	45·15	2·66	·30	3·38
29	14·65	+0·86	20·40	+1·19	33·46	+1·96	44·75	+2·62	285·29	+3·35

Longitudes $u-U$ of the satellites in their orbits reckoned from the points where they are at superior conjunction, and longitudes $U \pm 180°$ of the Earth, reckoned from the ascending node of the plane of the orbits on the plane of the equator:—

Greenwich Noon.	*Ariel.* u_1-U	Diff.	*Umbriel.* u_2-U	Diff.	*Titania.* u_3-U	Diff.	*Oberon.* u_4-U	Diff.	U.
1883.	°	1428°	°	868°	°	413°	°	267°	°
Jan. 9	249·34	·45	4·10	·74	52·84	·52	180·47	·39	5·52
19	237·79	·42	152·84	·72	106·36	·50	87·87	·38	5·55
29	226·21	·40	301·56	·69	159·86	·49	355·24	·36	5·59
Feb. 8	214·61	·37	90·25	·68	213·35	·48	262·60	·36	5·63
18	202·98	·34	238·93	·65	266·83	·47	169·96	·34	5·69
28	191·32	·31	27·58	·64	320·30	·46	77·30	·34	5·74
Mar. 10	179·63	·29	176·22	·63	13·76	·45	344·64	·33	5·80
20	167·92	·27	324·85	·61	67·21	·45	251·97	·33	5·86
30	156·19	·25	113·46	·61	120·66	·45	159·30	·34	5·92
Apr. 9	144·44	·24	262·07	·60	174·11	·45	66·64	·34	5·97
19	132·68	·23	50·67	·60	227·56	·45	333·98	·34	6·01
29	120·91	·22	199·27	·60	281·01	·46	241·32	·36	6·04
May 9	109·13	·22	347·87	·60	334·47	·47	148·68	·36	6·06
19	97·35	·23	136·47	·61	27·94	·48	56·04	·37	6·07
29	85·58		285·08		81·42		323·41		6·06

These values are to be interpolated for the times for which the positions of the satellites are required. The position-angles p and distances s from the centre of the planet are then found by means of the formulæ:—

$$s \sin (p-P) = a \sin (u-U),$$

$$s \cos (p-P) = b \cos (u-U).$$

The satellites move in the direction of increasing position-angles, and will be at their greatest elongations ("N" in position P + 90°, and "S" in position P − 90°), and at their superior (in position P) and inferior (in position P − 180°) conjunctions with the planet at or about the following hours, Greenwich Mean Time:—

Ariel.

		N.	S.				N.	S.				N.	S.	
1883.		h	d	h			h	d	h			h	d	h
Jan.	7	21·2	9	3·5	Feb.	24	18·5	26	0·7	Apr.	13	15·8	14	22·1
	10	9·7	11	16·0		27	7·0	28	13·2		16	4·3	17	10·6
	12	22·2	14	4·4	Mar.	1	19·5	3	1·7		18	16·8	19	23·1
	15	10·7	16	16·9		4	8·0	5	14·2		21	5·3	22	11·6
	17	23·2	19	5·4		6	20·4	8	2·7		23	17·8	25	0·1
	20	11·7	21	17·9		9	8·9	10	15·2		26	6·3	27	12·6
	23	0·1	24	6·4		11	21·4	13	3·7		28	18·8	30	1·1
	25	12·6	26	18·9		14	9·9	15	16·2	May	1	7·3	2	13·5
	28	1·1	29	7·4		16	22·4	18	4·7		3	19·8	5	2·0
	30	13·6	31	19·8		19	10·9	20	17·2		6	8·3	7	14·5
Feb.	2	2·1	3	8·3		21	23·4	23	5·6		8	20·8	10	3·0
	4	14·6	5	20·8		24	11·9	25	18·1		11	9·3	12	15·5
	7	3·1	8	9·3		27	0·4	28	6·6		13	21·8	15	4·0
	9	15·6	10	21·8		29	12·9	30	19·1		16	10·3	17	16·5
	12	4·0	13	10·3	Apr.	1	1·4	2	7·6		18	22·8	20	5·0
	14	16·5	15	22·8		3	13·9	4	20·1		21	11·3	22	17·5
	17	5·0	18	11·3		6	2·4	7	8·6		23	23·8	25	6·0
	19	17·5	20	23·7		8	14·9	9	21·1		26	12·2	27	18·5
	22	6·0	23	12·2		11	3·3	12	9·6		29	0·7	30	7·0

Umbriel.

1883.	N. h	S. d	S. h		N. h	S. d	S. h		N. h	S. d	S. h
Jan. 9	23·7	12	1·5	Feb. 24	13·8	26	15·5	Apr. 11	3·9	13	5·7
14	3·2	16	4·9	28	17·2	—		15	7·4	17	9·1
18	6·6	20	8·4	Mar.	—	2	19·0	19	10·9	21	12·6
22	10·1	24	11·8	4	20·7	6	22·4	23	14·3	25	16·1
26	13·5	28	15·3	9	0·2	11	1·9	27	17·8	29	19·5
30	17·0	—		13	3·6	15	5·4	May 1	21·3	3	23·0
Feb.	—	1	18·7	17	7·1	19	8·8	6	0·7	8	2·5
3	20·5	5	22·2	21	10·6	23	12·3	10	4·2	12	5·9
7	23·9	10	1·7	25	14·0	27	15·8	14	7·7	16	9·4
12	3·4	14	5·1	29	17·5	31	19·2	18	11·2	20	12·9
16	6·9	18	8·6	Apr. 2	21·0	4	22·7	22	14·6	24	16·4
20	10·3	22	12·0	7	0·5	9	2·2	26	18·1	28	19·8

Titania.

N. elong. 1883.	h	Inf. Conj.	h	S. elong.	h	Sup. Conj.	h
Jan. 9	21·6	Jan. 12	1·8	Jan. 14	6·0	Jan. 16	10·3
18	14·5	20	18·7	22	23·0	25	3·3
27	7·4	29	11·7	31	15·9	Feb. 2	20·2
Feb. 5	0·4	Feb. 7	4·6	Feb. 9	8·9	11	13·1
13	17·4	15	21·6	18	1·8	20	6·1
20	10·3	24	14·6	26	18·8	28	23·0
Mar. 3	3·3	Mar. 5	7·5	Mar. 7	11·8	Mar. 9	16·0
11	20·3	14	0·5	16	4·7	18	9·0
20	13·2	22	17·5	24	21·7	27	2·0
29	6·2	31	10·4	Apr. 2	14·7	Apr. 4	18·9
Apr. 6	23·2	Apr. 9	3·4	11	7·7	13	11·9
15	16·1	17	20·4	20	0·6	22	4·9
24	9·2	26	13·4	28	17·6	30	21·8
May 3	2·1	May 5	6·3	May 7	10·6	May 9	14·8
11	19·1	13	23·3	16	3·5	8	7·8
20	12·0	22	16·3	24	20·5	27	0·7
29	5·0						

Oberon.

N. elong.			Inf. Conj.			S. elong.			Sup. Conj.		
1883.		h			h			h			h
		—	Jan.	8	23·6	Jan.	12	8·4	Jan.	15	17·1
Jan.	19	1·9		22	10·7		25	19·5		29	4·3
Feb.	1	13·1	Feb.	4	21·8	Feb.	8	6·6	Feb	11	15·4
	15	0·2		18	9·0		21	17·8		25	2·6
	28	11·4	Mar.	3	20·2	Mar.	7	5·0	Mar.	10	13·8
Mar.	13	22·6		17	7·4		20	16·2		24	1·0
	27	7·8		30	18·6	Apr.	3	3·4	Apr.	6	12·2
Apr.	9	21·0	Apr.	13	5·8		16	14·6		19	23·4
	23	8·2		26	16·9		30	1·7	May	3	10·5
May	6	19·3	May	10	4·1	May	13	12·9		16	21·7
	20	6·5		23	15·3		27	0·1		30	8·8

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. JANUARY 12, 1883. No. 3.

E. J. STONE, M.A., F.R.S., President, in the Chair.

Frederick C. Green, Woodside Cottage, Breightmet, near Bolton, Lancashire;
Alexander Hamilton Howe, M.D., Hullerhirst, Stevenston, Ayrshire:
The Rev. J. Calbraith Lunn, Warrenpoint, Co. Down, Ireland;
S. T. H. Saunders, M.A., Merchant Taylors' School, E.C.;
Edmund Johnson Spitta, L.R.C.P., Ivy House, Clapham Common, S.W.; and
William Henry Walmsley, 35 Limes Grove, Lewisham, S.E.,

were balloted for and duly elected Fellows of the Society.

Observation of the Transit of Venus 1882, *December* 6, *made at the Allegheny Observatory.* By Professor S. P. Langley.

(*Communicated by E. B. Knobel.*)

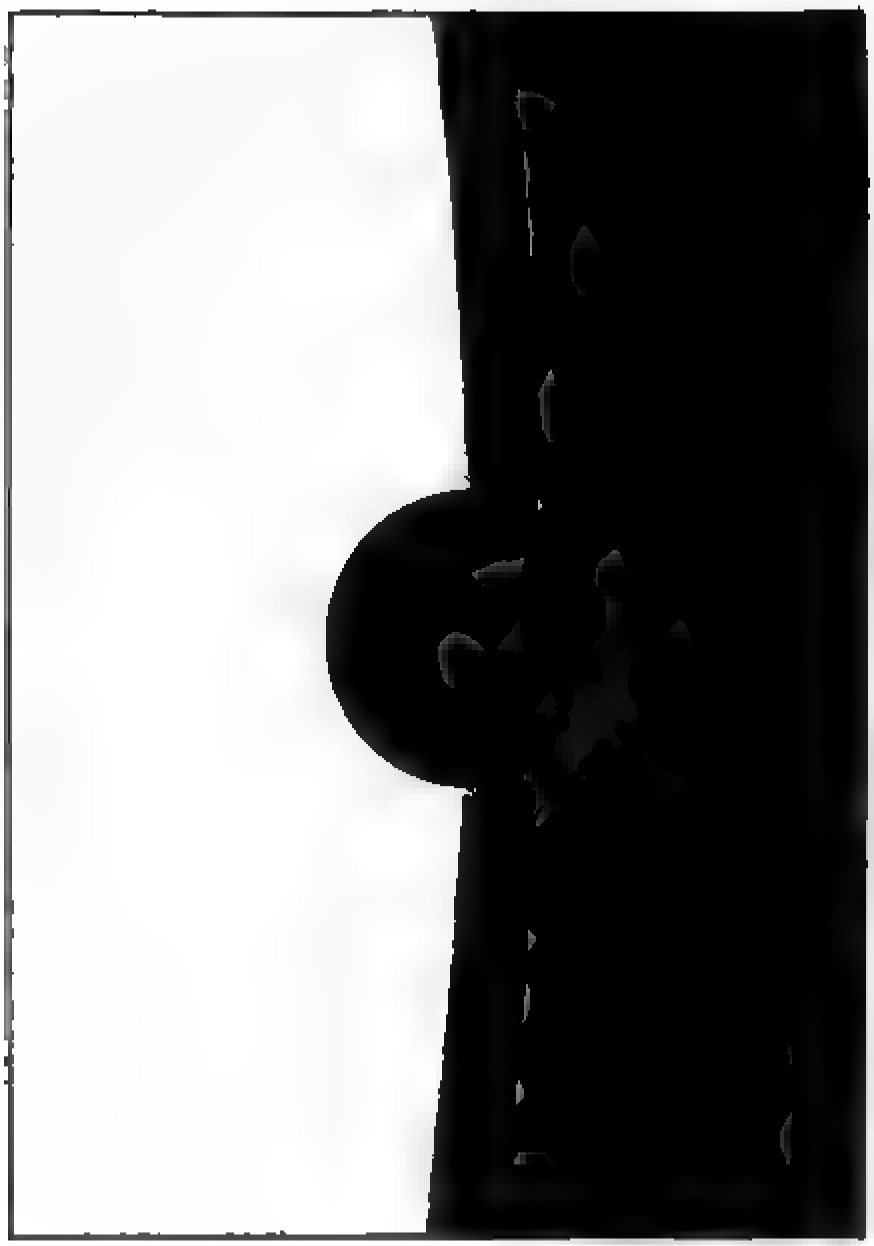
The observation of the Transit of *Venus* was so interrupted here by clouds yesterday that the times of contact have little value. A very unexpected and, I think, new phenomenon was noted however, connected with the luminosity about the planet, which deserves description in detail.

The telescope employed by the writer was the Equatorial of 13 inches aperture, temporarily limited to 6 inches, and used with a positive power of 244 upon the polarising solar eyepiece, which does not admit of a position circle.

The planet (whose first external contact was noted here at $20^h\ 44^m\ 15^s$, the first internal contact being at $21^h\ 5^m\ 0^s$) was seen through thin clouds which were passing incessantly over the Sun's face. At $20^h\ 47^m$, the part of the planet already on being conspicuous, the limb was boiling badly, and the anticipated ring of light around the exterior part of *Venus* was not visible. After an interruption, observation was resumed at about $20^h\ 53^m$, and a remarkable change was noticed. The planet was now nearly half entered on the disk, and still showed no uniform ring of light, but a very notable gathering of brightness, extending along some 30° of its southern and western circumference (outside the limb of the Sun). The centre of this bright marginal segment was estimated, from a rough sketch made at the telescope, as being about 30° on one side of a line joining the centres of the Sun and planet, and its asymmetrical position with reference to the horns of the solar crescent was conspicuous. The light was prolonged very faintly up to the Sun's edge on the western side, the eastern part of the planet being at this time scarcely yet distinguishable (as seen through the light haze) from its black background.

At $20^h\ 57^m$, after an interruption by clouds, the line of light could be followed all round, as described by previous observers, but the bright marginal enlargement of this ring remained unchanged. At $21^h\ 0^m$ (five minutes before internal contact) this bright spot was still visible. It was therefore watched by me, with occasional interruptions, for about seven minutes. Owing to the boiling of the limb, it was not easy to determine how much of this light lay without, how much within, the planet's contour. When first seen, it suggested for a moment the appearance of Baily's Beads, but the writer's very strong final impression was that it at any rate extended to some degree within the planet, and was brightest on the outside, with a slight gradation toward the planet's centre. Its greatest width was estimated at one-fourth of the planet's radius. Every precaution was taken against instrumental error. The spot was successively examined in different parts of the field, the eyepiece was rotated, and the amount of light from the reflectors was varied. It was beyond any question a real, if a most unexpected and unintelligible phenomenon, and it seems to me that it points to a real local cause on the planet. It does not appear to be at all assimilable to the concentric spots which some observers have believed they saw both on *Venus* and on *Mercury* in transit, nor to the alleged phosphorescence on the dark side.

At the same time Mr. J. E. Keeler, my assistant, using a telescope of only 2¼ inches aperture and a power of 70, independently observed and sketched the same phenomenon, though, owing to the size of his instrument, he appears not to have seen it in quite the same detail. He first saw it distinctly at $20^h\ 49^m\ 20^s$ (during the time in which the writer was called away from his own instrument), but had indistinctly noted it



Spot of light seen on Venus when entering on the Sun 1882, December 6.

From a drawing by Prof. S P Langley

W H Wesley del.

West, Newman & Co imp.

fully a minute before, when he describes it as looking like a little star.

Mr. Keeler's impression was, that the light lay chiefly or wholly *outside* the planet's contour. His memorandum sketch made at the telescope places the brightest point 20° of the planet's circumference to the west of the line joining the centres of the Sun and *Venus*. He saw it at intervals for over eight minutes, and records it as still visible at $20^h\ 58^m\ 11^s$.

It will be seen that the two independent estimates differ from each other by 10° as to the spot's position. If we take their mean, and assume that the position-angle of the planet itself on the Sun at the time was 148°, we obtain 173° as the position-angle of the bright spot, a line through which and the planet's centre would, as it readily appears, make an apparent angle of 76° with the plane of the ecliptic. After internal contact the limb of *Venus* was spectroscopically examined for absorption lines, but without effect. Clouds put an end to these latter observations before any result was reached other than that if any such absorption exists it is inconspicuous in the regions near D.

A drawing copied from my own sketch of this very curious phenomenon is here given.

Allegheny Observatory, Pa.:
1882, *Dec.* 7.

Le passage de Vénus observé à l'Observatoire de Moncalieri. Par le P. F. Denza.

Nous nous étions préparés à observer avec le plus grand soin possible les deux premiers contacts, extérieur et intérieur, et à faire l'une ou l'autre des observations raccomandées dans les instructions que l'Observatoire de Washington a publiées pour cette circonstance. Je dirai ici un mot de quelques-unes parmi les plus intéressantes.

Avant que le phénomène commençât, la partie occidentale du ciel, où se trouvait le soleil, fut encombrée de nuages stratiformes, qui, en devenant tantôt plus rares, tantôt plus denses, rendaient le bord solaire extrêmement agité, et par suite rendaient l'observation incertaine. Et cette portion du ciel se maintint dans cet état jusqu'au coucher du soleil.

Ce fut pour cela que nous dûmes renoncer à quelques observations spectroscopiques, que nous nous étions proposé de faire. Par contre, nous nous occupâmes à déterminer avec la plus grande attention qu'il nous fut possible, les instants des deux contacts. J'observais au réfracteur de Merz de 4 pouces d'ouverture. Le grossissement employé fut 54 pour le contact extérieur, et de 120 pour le contact intérieur.

Voici les résultats que nous avons obtenus :

		h m s		
Premier contact extérieur		2 49 31·0	temps moyen de Rome.	
„	intérieur	3 9 54·4		

L'instant du contact intérieur passé, lorsque le disque obscure de *Vénus* s'était déjà détaché du contour solaire, on vit assez bien encore uni à ce dernier au moyen de la *goutte noire.*

Selon nos déterminations, ce ligament se détacha complètement à $3^h\ 10^m\ 37^s{\cdot}8$.

Je fus attentif à observer si, après le contact extérieur, on distinguait autour du disque de la planète l'auréole de lumière, indice de l'atmosphère de *Vénus*, éclairée par le soleil ; mais je ne pus rien découvrir, pas même sur la portion du contour plus rapprochée du soleil, l'air étant toujours voilé et quelque peu agité.

Le disque de *Vénus* n'apparut entièrement noir ; il avait une teinte entre le rouge faible et le jaune sombre, le contour oscillant, à cause de la trop grande quantité de vapeur, dont l'influence allait toujours en augmentant à mesure que le soleil s'approchait de l'horizon.

C'est pour cela que les déterminations du diamètre de la planète ($67''{\cdot}12$), que nous avons prises, ne sont pas trop sûres.

De l'Observatoire de Moncalieri :
1882, 8 *Décembre.*

Observation of the Transit of Venus 1882, *December* 6.
By the Rev. R. P. Davies.

As so very many observers in England were prevented from seeing anything of the Transit in consequence of an overcast sky, and others missed the contacts through cloud, I venture to send the following, having been exceptionally well favoured. From two or three minutes before external to some considerable time after internal contact there was nothing to mar the view. No attempt was made to note the time of external contact, the image of the Sun being thrown upon a screen in order that a party of friends might see the advance of the planet upon the disc at the same time. After the lapse of about twelve or fifteen minutes, a first surface reflecting prism, negative eyepiece, and neutral-tint glass shade were affixed, and I was left in the Observatory alone with only an attendant to watch and count the clock. There were thus about five or six minutes to follow the planet to internal contact. The attention was especially arrested by the aureole with its delicate tint. As the time of internal contact approached there was a phase at which it seemed well to mark the *second*, as it might turn out to be that which

answered best to the requirements of the "Instructions," p. 3, under "At Ingress." Nevertheless I felt satisfied that it was not contact, and that the appearance was still partly due to the light refracted through the planet's atmosphere. Nine seconds afterwards there was an unmistakable junction of the cusps of the Sun's surface; or, as I find it in my notes, written on the day and not touched since, "strip of sunlight unmistakable." This was at local sidereal time $19^h\ 16^m\ 4^s$, which when converted into G.M.T. (the longitude being $7^m\ 6^s{\cdot}2$ W.) gives $2^h\ 22^m\ 6^s{\cdot}32$.

There was but a very little distortion of the planet's form, and very little of the black drop; a striking contrast with that which baffled me when observing the egress of *Mercury* in the transit of November 1868. After the time noted, and probably after returning from the clock, I observed a faint fine line, "like a cobweb for fineness," connecting the planet with the limb of the Sun, the planet being then well on the disc. I regret to say that the moment when this disappeared was not noted.

The telescope is equatorially mounted and driven by a clock: its aperture, 4 inches; the power used, 60. The latitude and longitude of my Observatory are 51° 44′ 40″ N., 1° 46′ 32″·5 W.

Hatherop Rectory, Fairford, Gloucestershire:
1883, *Jan.* 9.

Observation of the Transit of Venus 1882, *December* 6, *made at Marseilles.* By the Rev. S. J. Johnson.

I observed the Transit from an upper window in the Hôtel Louvre et de la Paix in the city of Marseilles, having obtained time from the Observatory. The only instrument at my disposal was a 2½-inch telescope by Cooke. At the time of internal contact the Sun was visible through light clouds. No higher power than 70 could be employed, and no dark glass was necessary. At $2^h\ 39^m\ 47^s$ (local time) the limbs seemed in contact, but actual sunlight did not appear round the planet until $2^h\ 42^m\ 36^s$ (local time), somewhat suddenly. This would probably be true internal contact. At $2^h\ 46^m$ the Sun shone out brighter, and a power of 150 showed *Venus* well defined, and without the least trace of any ring of light. Through a darkened glass the planet was distinctly visible to the naked eye (and was so seen by numbers of persons at Bridport). After $3^h\ 18^m$ the planet began to boil, and after $3^h\ 22^m$ the clouds thickened.

Melplash Vicarage, Bridport:
1883, *Jan.* 8.

Observation of the Transit of Venus 1882, December 6, made at Fernhill, Wootton Bridge, Isle of Wight. By Frederick Brodie.

So few persons in England seem to have had a view of this Transit, that I send a few remarks on the little that was visible here.

The whole period of the Transit visible in these latitudes was more or less obscured by clouds. The external contact was not seen, but at $2^h\ 3^m$ L.M.T. the planet was seen partly on the Sun's disk. The internal contact took place between $19^h\ 18^m$ and $19^h\ 18^m\ 6^s$ L.S.T. It was quite impossible to obtain any exact observation, as the great amount of aqueous vapour that was passing made the definition of the disks of planet and Sun of maximum unsteadiness. It could hardly be worse. I was using a power of 80 on the $8\frac{1}{4}$ in. Equatorial, and generally only with a dark glass used as a moonshade, so seldom was the Sun free from cloud more or less.

When the planet's disk was about half way on the Sun's periphery, I got a short view, showing me with great clearness the twilight caused by the atmosphere of *Venus* all round that portion of her disk as yet off the Sun. It was a soft white light, assuming a ruddy hue next to the edge of the planet's disk. The effect of it was beautiful, and this continued nearly until the time of internal contact. It was at once evident that the extent of the atmosphere round the planet was infinitely greater than that accorded to our own planet. This was also clearly seen in a telescope by Merz of 3 in. aperture that my son was using.

After the planet was on the Sun's disk about an hour, the southern half of the planet's disk was fringed with an intense blue colour, and the northern half of the disk with a reddish orange. This effect was also clearly seen in the 3 in. Merz telescope. This was not due to the position of the planet in the field of the eyepiece, as is often the case in a lesser degree, but was, apparently on account of the low elevation, in a bad state of atmosphere. The longest continuous view I had was not more than two or three minutes on the one occasion of internal contact; at other times I only had glimpses of much shorter duration.

The observation was made with an Equatorial of $8\frac{1}{2}$-inch aperture by Cooke & Sons.

Observations of the Solar Spots of November 1882. By Frederick Brodie.

The large solar spots, concerning which notes were given by Messrs. Howlett and Pratt in the *Monthly Notices* for May last, have, I think, been surpassed in size by those of November.

The huge crater, or *penumbra*, in which these spots, or *umbræ*, were situated, was the largest that I remember to have seen, and far larger than that which occurred in October 1865, which was mentioned then in the *Notices* of the R.A.S. by the Rev. F. Howlett and myself, and which was especially interesting on account of the extreme rapidity of the photospheric changes.

November 15.—The spot now visible on the Sun is an immense size. The *penumbra* is of an irregular oval shape, and measures across its major axis 128″, equal to 56,000 miles; while its minor axis measures 116″, or 51,000 miles. The *umbra* is most irregular in shape, measuring in its greatest length 39,000 miles, and its greatest breadth 23,000 miles. The changes in its outline are very rapid, so much so that it is most difficult to sketch, in addition to which the low altitude of the Sun and correspondingly bad definition render it increasingly difficult. The *umbra* has six large and long promontories stretching more or less across it, something like the fingers of the hand, only that they are curvilinear. The rugged glacier-like form of the sides of the *penumbra* is most remarkable, but the atmosphere is too bad to make measurements of details.

Clouds prevented further observation for some days.

November 19.—The great spot has greatly altered in its details. There is now a nest of *umbræ* within the one *penumbra*, which has not materially altered in shape, though it is enlarged, its greater length now being 64,000 miles, and its breadth 52,000 miles. The extreme activity of the photosphere continues, and is far greater than what I have ever noticed before. Within three hours two of the larger *umbræ* had joined themselves together, and had again separated. The channel of communication between them that was opened and again filled up was roughly estimated at about 2,000 miles wide and 8,000 or 9,000 miles long.

The extremely bad definition and the unsteadiness of atmosphere render it impossible to observe or measure the small details, while the excessively cloudy weather prevents anything more than occasional views of the Sun, otherwise this spot would have formed a study of surpassing interest.

The instrument employed was an Equatorial of 8½ in. aperture by Cooke & Sons.

The Spectrum of the Great Sun-spot of 1882, *November* 12–25, *observed at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The spectrum of this remarkable spot was examined by means of the "half-prism" spectroscope on three occasions, viz., Nov. 18, 20, and 21. The weather in each instance was very unfavourable for a satisfactory examination, being misty and cloudy on Nov. 18 and 20, and on Nov. 21 the Sun was only visible

through a yellow fog. A detailed examination of any but the most conspicuous lines was therefore out of the question.

Nov. $17^d\ 23^h$–$18^d\ 1^h$.—The following lines were observed to be reversed, *i.e.*, bright instead of dark over the principal nucleus of the spot:—C, D_1, D_2, D_3, and F. Of these, C and F were exceedingly bright, particularly F; and this, notwithstanding that the mist enfeebled the blue and violet portions of the spectrum. D_3 was only perceived for a short time, apparently when the mist was lightest, about $23^h\ 50^m$. D_1 and D_2 were not only reversed but extravagantly broadened, each line forming a very broad and ill-defined dark band, quite 6 tenthmetres in breadth, with a sharp, narrow, bright line in the centre, apparently at the normal place of the line. This appearance, and the reversal of D_3, were noticed whenever the definition and light were a little better than usual. The reversal of C and F took place over the bright tongue, which all but divided the largest nucleus of the spot into two nearly equal portions. The reversal of the sodium lines was not noticed at the point where C and F were brightest.

The third and fourth lines of hydrogen could not be detected, but the mist made it impossible to observe the extreme ends of the spectrum.

The *b* lines and 1474 K showed no appreciable change. The strong calcium lines between C and D were doubled in breadth. The E lines were less strongly affected, and were perhaps one-third as broad again as usual.

The *general* absorption of the spot was small: that is, the continuous spectrum was not so much fainter than that of the general disk as might have been expected.

Nov. $19^d\ 23^h$–$20^d\ 0^h$.—The *general* absorption was more marked than on Nov. 18, and more lines were noticed to be broadened. The general absorption was not, however, uniform; here and there, there were broad, ill-defined patches, noticeably darker than the rest of the spectrum. The district lying between λ 4900 and λ 4830 was one of the most marked of these.

The C line was seen reversed right across the great nucleus; D_3 and F were suspected to be reversed, but, owing to the mist, could not be clearly seen as bright lines. D_1 and D_2 also could not be seen as bright lines, but they presented exactly the same appearance as they had done on Nov. 18, at times when the mist was too dense to permit the reversal to be clearly seen. That is, they were very much broadened, were very ill-defined, and much fainter than usual in the middle. Several other lines, amongst them λ 4957, λ 4920, and λ 4918, closely resembled the D lines. The 1474 K line did not appear to be affected, but one near it, either λ 5301 or λ 5307,—there was not time to properly identify the line, but it was believed to be λ 5307,—vanished over the spot.

The calcium and iron lines between C and D were much broadened, and also those near λ 5600 and λ 5856. These were broader by about two-thirds; the E lines were broader by about

one-half, the *b* lines by one-quarter. All these lines were, as a rule, well-defined, that is to say, they did not show the "smudged" appearance seen in the D lines, and the three iron lines near F, mentioned above.

The foregoing observations, both on Nov. 18 and 20, were all made with the "half-prism" spectroscope reversed, that is, with the instrument arranged as for observation of the prominences, so as to give great purity. Two "half-prisms" were employed. The spectroscope was afterwards placed in the direct position, as used for observation of stellar spectra, and only one "half-prism" was employed. With this dispersion, a remarkable reversion of the F line was noticed. At the preceding edge of the great nucleus, there was a broad bright flame, which, touching the F line at the extreme preceding edge of the nucleus, sloped away from the nucleus in the preceding direction, and from the F line towards the blue. It was inclined to the F line at an angle of about 40°, was 1 or perhaps 1¼ tenthmetre in average breadth, and extended to a distance from the F line of 3 or perhaps 3½ tenthmetres. It was pointed at each end, and was nearly but not quite straight, being a little twisted near its centre. A displacement of 3½ tenthmetres towards the blue would correspond to a motion of approach of 134 miles per second. Time of observation Nov. 19^d 23^h 20^m.

Nov. 21.—The sun was only seen through fog and was very faint. The spot-spectrum was therefore a dense black band in which it was very difficult to perceive any details. The "half-prism" spectroscope reversed, with two "half prisms," was used throughout the morning. The C and F lines were reversed over the greater portion of the area of the spot, not, however, over the very darkest part of the principal nucleus, but over all its fainter portions. D_3 and perhaps 1474 K seemed to be reversed over the same region. The latter line seemed to be displaced nearly 1 tenthmetre towards the red. The D lines together covered quite 10 tenthmetres, and ran one into the other; they were very ill-defined, and appeared exactly as on Nov. 20. They extended further towards the blue than towards the red, in fact, the broadening seemed traceable twice as far in the first direction as in the second. A very large percentage of the lines between D and F had a similar appearance to that shown by the D lines and the iron lines near F on Nov. 20; *i.e.*, they were very much broader than on the general disk, were very ill-defined, and were much fainter than the corresponding lines on the Sun, especially about their centres. It is, therefore, probable that a clearer day would have shown them as distinctly reversed, especially as the F line showed precisely the same "smudged" appearance whenever the fog became too thick for it to be seen as a bright line.

Group *a* and the lines at λ 6200 were very much broadened, principally on the side nearer the blue.

A momentary gleam of clearer sunlight showed F reversed in the most intricate and beautiful manner right across the great

nucleus—not over its entire area, but at short intervals from one side to the other, even over its blackest portion. These stars of brilliant blue light were on the average about twice as broad as the dark F line on the general disk, sometimes four times as broad, and were but little displaced, if at all.

The observations were made by Mr. Maunder throughout.

Royal Observatory, Greenwich:
1883, *Jan.* 12.

Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the Year 1882. No. VI.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. xxxvi. p. 318, vol. xxxvii. p. 22, vol. xxxviii. p. 493, vol. xli. p. 109, and vol. xlii. p. 230. The observations were made with the "half-prism" spectroscope, one "half-prism" with a dispersion of about $18\frac{1}{2}^{\circ}$ from A to H being used. An eyepiece with a magnifying power of 14 was employed throughout.

Up to 1882, March 13, a convex cylindrical lens, with its axis parallel to the length of the spectrum, and placed in the view-telescope within the focus, and a concave or Barlow lens of 2 inches focus placed in the collimator between the slit and the object-glass, as used throughout the year 1881, were employed. On March 14, the Barlow lens was removed, and the cylindrical lens was placed in front of the slit, as in the observations made previously to 1881. In most of the observations a diaphragm coated with Balmain's luminous paint has been used in the micrometer-adapter to give a phosphorescent illumination of the field.

The observations of the Moon and of the sky spectrum have been made as a check on the general accuracy of the results.

Motions of Stars in the Line of Sight, in Miles per Second, observed with the Half-prism Spectroscope.

(+ denotes Recession; − Approach.)

The initials M. and N. are those of Mr. Maunder and Mr. Nash respectively.

Date.	Obs.	No. of Meas.	Line.	Earth's Motion in M. per sec.	Concluded Motion of Stars. Meas.	Estimd.	Remarks.
					β Cassiopeiæ.		
1882.							
July 24	M	2	F	−11·2	+34·1	+33·9	Clouds constantly passing. Observation unsatisfactory.

Date.		Obs.	No. of Meas.	Line.	Earth's Motion in M. per sec.	Concluded Motion of Stars. Meas.	Estimd.	Remarks.
						γ Pegasi.		
1882								
Nov.	9	M	2	F	+11·8	−41·1	−39·6	Definition poor.
						β Persei.		
Nov.	9	M	2	F	− 2·1	+18·1	+17·3	Definition fair.
						α Persei.		
Nov.	8	N	1	F	− 4·2	−30·2	−30·3	Definition good.
						Capella.		
Oct.	20	N	2	b_1	−13·7	+33·4	+28·2	Observation unsatisfactory.
Nov.	9	M	2	F	− 9·3	+22·5	+22·6	Definition fair.
	10	N	2	F	− 9·1	+19·9	+24·8	„ good.
						γ Orionis.		
Feb.	10	M	3	F	+16·0	+8·5	+ 5·4	Cloud passing. Measures made with difficulty.
						β Tauri.		
Feb.	10	M	3	F	+16·4	−34·0	−31·3	Definition good.
						γ Geminorum.		
Mar.	14	M	4	F	+18·0	−26·4	−27·4	Definition poor.
						Sirius.		
Feb.	10	M	6	F	+ 9·3	− 1·7	− 3·3	Definition good.
Mar.	14	M	5	F	+13·6	+ 0·7	+ 6·4	Definition good.
Apr.	5	M	3	F	+14·1	+10·9	+15·4	„ fair.
	8	M	6	F	+14·0	+ 8·2	+ 8·9	„ good.
						Castor.		
Feb.	10	M	4	F	+10·3	+19·9	+15·3	Definition fair.
Mar.	14	M	3	F	+16·7	+ 8·5	+18·0	„
Apr.	5	M	2	F	+18·0	+22·5	+24·4	„
						Procyon.		
Feb.	10	M	2	F	+ 8·5	+27·6	+24·1	Definition good.
Mar.	14	M	4	F	+15·5	+ 3·2	+ 9·3	Definition fair.
Apr.	5	M	2	F	+17·4	+18·8	+21·5	„
						Pollux.		
Feb.	10	M	4	F	+ 9·3	−14·4	−12·1	Definition good.
Mar.	14	M	2	F	+16·3	−40·3	−43·6	„ poor.

Date.	Obs.	No. of Meas.	Line.	Earth's Motion in M. per sec.	Concluded Motion of Stars. Meas.	Estimd.	Remarks.
					δ Leonis.		
1882.							
Apr. 8	M	2	F	+11·2	−35·0	−35·5	Definition fair. Spectrum steady.
					θ Leonis.		
Apr. 8	M	3	F	+10·9	+ 5·7	+ 4·0	Star-line broad and faint.
					α Virginis.		
Apr. 8	M	4	F	− 0·1	−21·2	−22·3	Spectrum bright, but tremulous.
					Arcturus.		
June 12	M	2	F	+13·2	−30·4	−28·6	Definition good.
Aug. 8	M	2	b_1	+14·1	−54·8	−69·1	„ poor.
	N	1	b_1	+14·1	−53·9	−69·1	
					β Libræ.		
June 12	M	2	F	+ 9·9	−37·5	−38·7	Spectrum very faint.
					α Coronæ.		
Apr. 8	M	2	F	− 4·8	+18·8	+21·6	Definition poor.
June 14	M	4	F	+ 8·7	+41·2	+35·5	„ good.
					α Ophiuchi.		
June 14	M	4	F	− 0·8	+31·6	+28·7	Definition fair.
July 10	M	2	F	+ 6·7	−41·2	−45·2	Definition good, but spectrum faint.
					γ Draconis.		
Aug. 21	M	2	b_1	+ 4·2	− 9·0	−10·2	Wind high. Definition poor.
					α Lyræ.		
June 14	M	2	F	− 2·9	−26·7	−27·9	Definition good.
July 29	M	2	F	+ 3·3	−42·0	−45·0	Spectrum fairly steady.
Aug. 4	M	2	F	+ 4·1	−34·5	−28·8	Definition good.
Nov. 8	N	4	F	+ 7·5	−53·2	−46·4	Spectrum very bright.
					ζ Aquilæ.		
Aug. 2	M	2	F	+ 5·5	−20·1	−21·8	Spectrum faint. Observation unsatisfactory.
					β Cygni.		
Aug. 21	M	4	b_1	+ 5·8	−28·2	−34·2	Wind high. Definition very poor.

Date.	No. Obs. Meas.		of Line.	Earth's Motion in M. per sec.	Concluded Motion of Stars. Meas.	Estimd.	Remarks.
					γ Aquilæ.		
1882.							
Aug. 8	M	2	b_1	+ 4·5	−21·8	−20·9	Definition good.
	N	1	b_1	+ 4·5	−16·0	−4·5	
					α Aquilæ.		
June 14	M	4	F	− 9·2	−22·2	−18·3	Definition good.
July 12	M	2	F	− 2·6	−33·3	−41·1	Spectrum faint. Cloud forming.
Aug. 2	M	2	F	+ 2·8	+13·1	+16·7	Definition good.
					γ Cygni.		
Aug. 21	M	2	b_1	+ 1·0	−16·1	−21·0	Wind high. Definition poor.
					α Delphini.		
Aug. 2	M	2	F	− 1·4	−10·9	−11·6	Spectrum faint. Observation unsatisfactory.
					α Cygni.		
July 15	M	2	F	− 5·8	−28·2	−30·9	Definition variable.
Aug. 4	M	2	F	− 3·2	−17·0	−17·4	„ good.
	N	2	F	− 3·2	−16·6	−16·0	
Aug. 21	M	2	b_1	− 0·8	−31·0	−49·1	Wind high. Definition fair.
Oct. 7	M	2	b_1	+ 6·0	−42·2	−53·9	Spectrum faint, owing to mist, but steady.
					ζ Cygni.		
Aug. 21	M	2	b_1	− 0·6	+ 0·8	+ 0·6	Definition poor.
					η Pegasi.		
Aug. 8	N	2	b_1	− 9·0	+ 1·2	+ 0·8	Definition fair.
	M	2	b_1	− 9·0	+ 9·5	+ 9·0	
					α Pegasi.		
July 24	M	2	F	−12·8	− 13·3	−18·7	Clouds passing. Observation unsatisfactory.
Aug. 2	M	2	F	−11·1	− 8·9	− 9·8	Definition good.
Nov. 9	M	4	F	+14·6	−46·7	−43·0	Definition very poor.
					Moon.		
July 29	M	5	F		− 3·0		Moon spectrum faint. Definition fair.
Aug. 2	M	5	F		+ 2·6		

Date.	No. Obs.	of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Stars. Meas.	Estimd.	Remarks.
1882.					*Sky Spectrum.*		
Feb. 11	M	5	F		+ 1·2		Hydrogen spectrum faint; comparison difficult.
Mar. 14	M	5	F		+ 2·7		
Apr. 6	M	5	F		− 3·9		

Royal Observatory, Greenwich:
1883, *Jan.* 12.

Observation of the Great Comet (b) 1882, *made with the Transit Circle at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

	Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D. (Corrected for Refraction and Parallax.)
1882.	h m s		h m s	° ′ ″
Nov. 26	16 37 31	A.D.	9 1 29·93	117 46 39·59

Comet very faint; appeared elongated in a direction inclined 45° to the parallel of declination. The brightest part at about one-third of the way from the north end of the elongation to the south was observed.

Royal Observatory, Greenwich.
1883, *Jan.* 12

Observations of the Great Comet (b) 1882.
By Charles Leeson Prince.

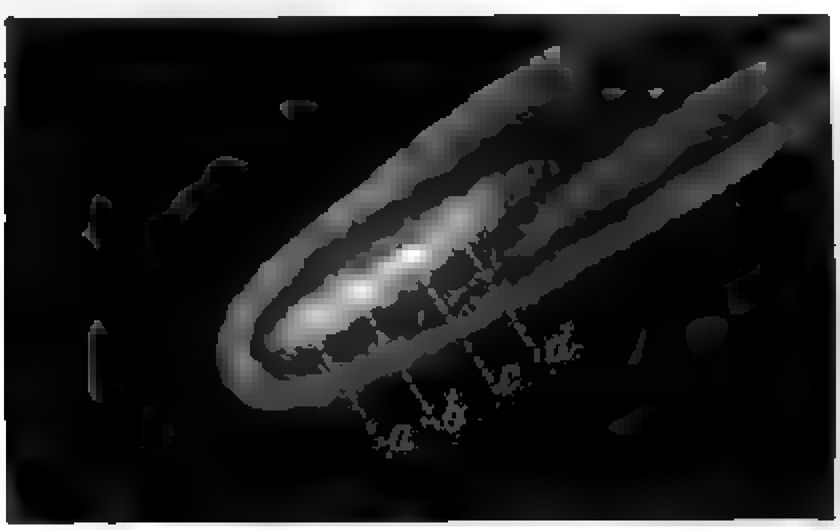
The Society has doubtless received, and will continue to receive, many details of the appearance of the great comet which has lately visited our region in space, and as the weather during the month of October, which was the most important period for making good observations in England, was extremely unfavourable, I beg to forward to the Society a few notes of what I was able to record at my Observatory upon the only possible opportunities. My first view of the stranger was at 5 A.M. on Oct. 4, and my first impression was that its general aspect was grander than that of Donati's in 1858, and exceeded in brilliancy of detail the great comet of 1861. As the nucleus was much enveloped in a mist which lay along the horizon, it was not very well defined in the telescope, but appeared to be oval, or pear-shaped, of a diffused orange colour, and without any very definite appendage surrounding it. The tail was nearly 25° long, and of great breadth at its extremity. I had no further opportunity of seeing it again until the morning of the 10th, when it was decidedly brighter than on the 4th; but this effect might have been partly due to my time of observation having been somewhat earlier.

The tail, at its extremity, had a brilliant silvery light, and a peculiar flocculent appearance, against the dark sky. It extended nearly to *a Hydræ*. A few small stars were visible through it without, I think, having their brightness diminished. To the naked eye, I thought the brightness of the nucleus was about equal to that of a star of the second magnitude. On account of clouds coming up from SE. I had very little time for observation this morning.

Oct. 13.—I saw the comet again this morning, for a short time, but the definition was very unsatisfactory on account of the disturbed condition of the atmosphere. I could notice, however, that there was a decided change in the appearance of the nucleus. Instead of being of an oval shape it had become a long flickering column of light in the direction of the tail. The comet was very impatient of daylight, and could not be seen in the telescope after sunrise.

Oct. 20.—On account of the presence of clouds I did not see the comet this morning until the dawn had considerably advanced. I noticed, however, at once, that a still further change had occurred in the nucleus since the 13th, which amounted, in fact, to its disruption into at least three portions. Unfortunately, the definition was much interrupted by a thin layer of cirrostratus cloud. The brightest portion was the central one, and the column of light, seen on the 13th, had become narrower as well as lengthened in the direction of the tail. The southernmost portion was extremely faint and required some attention to be seen at all.

Oct. 23.—I had a splendid view of the comet this morning at $4^h\ 30^m$ L.M.T., and the definition was extremely good. I thought that both the nucleus and tail had somewhat diminished in brilliancy. The former was still visible to the naked eye as a star of about the fifth magnitude. The length of the tail was was fully 20°. The disruption of the nucleus which I had noticed on the 20th was now fully apparent. The nucleus proper had become quite linear, having upon it the four distinct points of condensation which I have endeavoured to represent in the subjoined sketch.



It must be understood that the accompanying woodcut is to be considered rather as a *diagram* of the head of the comet than as a *view* of what I actually observed, and that the *points* in question are somewhat exaggerated in size, as well as the linear character of the nucleus itself. I found it was very difficult to represent, by means of a wood block, such a nebulous object; but I think it will serve to illustrate the nature of the wonderful disruption, and the relative distance of the several portions *inter se*: *a* was the most difficult portion to discern; *b* was by far the brightest of all; *c* was considerably less bright than *b*; and *d* was nearly as faint an object as *a*, and not quite so large. The linear nucleus, with these points of condensation upon it, was surrounded by a distinct oblong coma, which was rounded off at the lower extremity, while the upper portion, following the direction of the tail, terminated more decidedly in a point. G. J. Symons, Esq., F.R.S., was with me in the Observatory, and his impression was that there were *five* points of condensation, and he remarked that "the nucleus was like a string of beads." At intervals I thought there *was* another point of light between *b* and *c*, but as I could not absolutely satisfy myself of its objective existence, I have only represented the four portions, of the presence of which I entertained no doubt whatever. Both Mr. Symons and myself particularly noticed the frequent flickering of the light of the nucleus, which was quite apparent both to the naked eye and in the telescope.

Oct. 30.—After the lapse of a week I had another opportunity of observing the comet, but found that the presence of moonlight considerably diminished its brightness. The nucleus was, however, quite visible to the naked eye, and shone brightly in a large opera-glass. The almost saturated condition of the atmosphere prevented any good definition being obtained by the telescope. The largest point of condensation still shone brightly, but the three smaller portions were scarcely visible—in fact, *a* could no longer be seen. The nucleus maintained its strictly linear form, but all its more interesting features were much less distinct. With respect to the general appearance of the tail, there was a dark, nearly central, space throughout its entire length, the southern side being the brighter of the two, more particularly midway its length. On the morning of the 10th it was curiously bifurcated, near to its extremity, and had somewhat the appearance of entangled bright cords, or scattered locks of wool.

These observations were made with my Tulley Equatorial of 6·8 inches aperture and 12 feet focal length; powers 30 and 80.

The Observatory, Crowborough:
1883, *Jan.* 2.

Sextant Observations of the Great Comet (b) 1882, *taken on board the ship "Earnock," on a passage from Glasgow to Melbourne.* By Capt. G. F. Parson.

(*Communicated by Capt. Henry Toynbee, R.N.*)

Date. 1882.	App. Time Ship. A.M.	Lat. S.	Long. W.	Obs. Alt.	Distances from Sirius.	Distances from Canopus.	Distances from α Crucis.	Remarks.
	h m	° ′	° ′	° ′ ″	° ′	° ′	° ′	
1882, Sept. 22	5 38	22 20	26 50	6 56 30	—	—	—	Stars more at a right angle would have been used, but daylight rendered these the only available ones, owing to their brilliancy.
24	5 10	28 42	26 52	—	64 47	74 54	—	
	5 21	,,	,,	7 20 0	—	—	—	
25	5 11	32 14	25 6	—	63 51	74 10	—	The body of the comet apparently equal to a star of the 1st magnitude.
		,,	,,	7 0 0	—	—	—	
28	5 6	39 20	13 46	—	61 34	71 43	—	Very brilliant.
		,,	,,	11 4 0	—	—	—	
29	4 51	40 7	11 20	—	60 52	—	—	
		,,	,,	—	—	70 57	—	
Not seen again until			E.					
Oct. 13	3 29	43 7	34 36	—	54 6	62 37	—	A good view; tail visible 19⅛° towards Orion's belt.
14	4 21	43 8	40 28	—	53 41	61 56	—	
Only an occasional glimpse until								
Oct. 24	3 13	41 21	84 25	—	49 50	57	—	
	3 20	,,	,,	21 26	—	—	51 20	Tail visible 17° towards Rigel.
31	2 20	40 30	113 5	—	47 11	53 19	—	Moon rather bright for good observations.
Nov. 2	3 39	40 37	123 29	—	46 30	52 48	—	
7	2 4	38 40	139 50	—	44 29	49 58	48 9	Tail 17½°.

Sextant Observations of the Great Comet (b) 1882, *made on board the ship "Superb."* **By Capt. D. W. Barker.**

(*Communicated by Capt. Henry Toynbee, R.N.*)

Date.	Lat. S	Long. W.	Stars used.	Distance from Comet.	Time by Chronometer G. M. T.	Remarks.
	° ′	° ′		° ′ ″	d h m s	
1882, Sept. 28	49 19	173 13	α Crucis	59 18 33	28 3 55 47	Tail about 9½° long. Bright clear morning.
			Canopus	71 13 8	3 57 0	
			Procyon	49 34 8	4 0 21	
Oct. 1	48 47	158 53	α Crucis	58 13 3	1 3 4 23	Tail about 11° long. Brightness comparable with α Orionis. Bright clear morning.
			Canopus	69 10 58	3 6 3	
			Sirius	59 24 23	3 7 38	
4	48 7	152 30	Sirius	57 47 44	4 2 47 51	More or less cloudy. Tail longer and less bright.
			Canopus	67 16 8	2 43 8	
5	48 26	150 46	α Centauri	67 24 59	5 1 16 15	Passing clouds. Tail extending directly towards α Hydræ, almost reaching it. Less bright.
			Canopus	66 39 59	1 17 38	
			Sirius	57 16 59	1 31 33	
13	50 48	112 41	Canopus	62 16 29	12 23 36 25	Tail getting fainter and longer. Fine and clear weather.
			Sirius	53 0 29	23 38 54	
30	45 56	45 14	β Centauri	58 25 25	29 17 3 12	Bright clear weather. Much fainter than when last observed.
			Canopus	53 42 45	17 12 35	

Date.		Lat. S.	Long. W.	Stars used.	Distance from Comet.	Time by Chronometer G. M. T.	Remarks.
		° ′	° ′		° ′ ″	d h m s	
1882, Oct.	30	45 56	45 14	Sirius	47 22 45	17 16 48	
Nov.	5	34 18	35 5	β Centauri	57 53 0	4 15 54 38	
				Canopus	50 4 40	15 53 6	Clear weather.
				Sirius	45 0 0	15 48 25	
	8	31 29	31 5	Canopus	43 23 35	7 15 49 44	Tail 17½° long. A splendid object. Tail broader, nucleus fainter. Passing clouds.
				Achernar	49 4 40	51 29	
				α Crucis	48 16 0	53 38	
	14	21 33	29 56	Canopus	45 13 10	13 18 7 26	
				α Centauri	61 42 15	9 25	Passing clouds, otherwise clear.
				Sirius	40 58 15	10 46	
Dec.	7	N. 20 20	36 15	Alphard	24 27 15	6 18 38 33	Fine and clear. A much fainter object. Nucleus situated about 1° W. of *f* Mali; tail to 16 Puppis.
				Sirius	28 51 10	42 52	
				Procyon	37 56 45	44 35	
	9	25 50	37 23	Sirius	27 34 55	8 19 14 52	Passing clouds.
				Procyon	37 46 45	17 8	
				α Hydræ	25 25 55	21 41	

Observations of the Great Comet (b) 1882, *made at Dalston, London, E.* By B. J. Hopkins.

(*Communicated by the Earl of Crawford.*)

The instrument with which the following observations were made is a refractor of five inches aperture. The full aperture, and a Ramsden eyepiece having a power of 107, was always used.

1882, *Nov.* 4, $17^h\ 0^m$.—The tail had an apparent length of 20°, and a breadth at the extreme end of 1° 30′. It slightly curved upwards, was very diffused at the end, and was divided into two portions by a dark rift for two-thirds of its length from the nucleus.

Nov. 4, $17^h\ 50^m$.—The nucleus was of a yellowish-white colour, oval in shape, with the major-axis in the direction of the tail, and surrounded with a dense nebulosity.

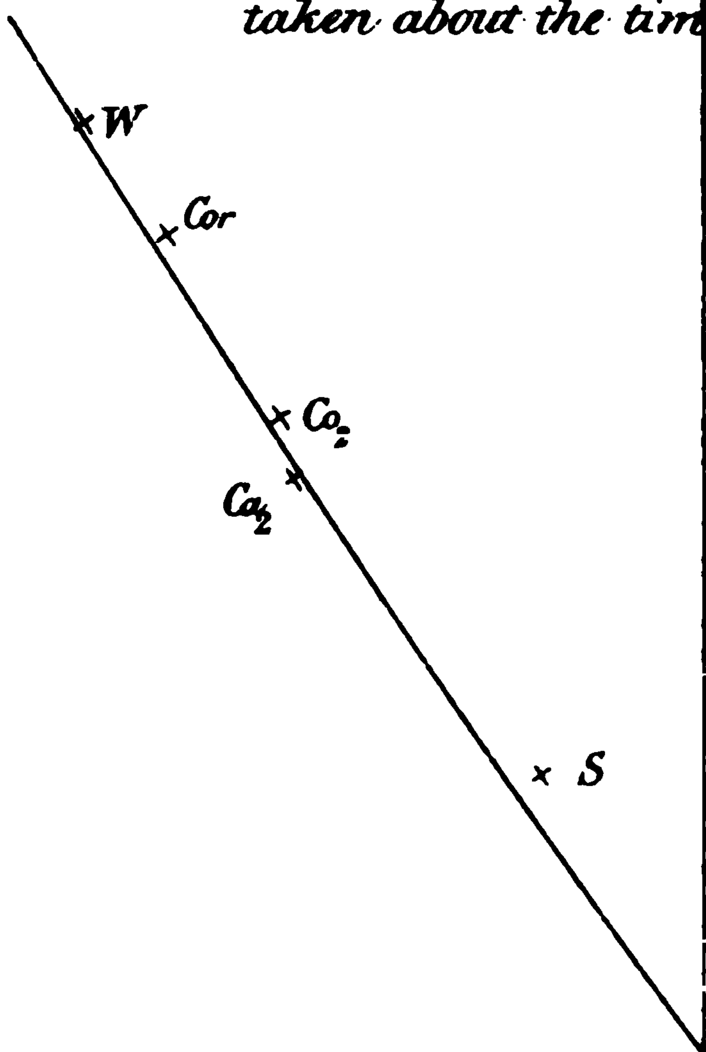
Nov. 8, $16^h\ 50^m$.—The tail could be distinctly traced for 19°. It was straight for four-fifths its length. It then abruptly curved upwards, and spread itself out in the shape of a fan, with a breadth of 4°. The dark rift was not so conspicuous as on the 4th inst., though the tail still remained brightest on the southern side.

Nov. 8, $17^h\ 30^m$.—The nucleus, as viewed by the naked eye, appeared equal to a second magnitude star. Observed with the telescope, a great change was seen to have taken place since last observed, for it now had the appearance of being double, there being two portions of equal brightness separated by a space of less brightness, the whole being surrounded by a dense circular nebulosity. The division between the two portions was only just seen, and the line joining them was at an angle with the axis of the tail.

Nov. 14, $15^h\ 45^m$.—The tail I now saw to much better advantage than I had hitherto observed it. It had a length of 30°, and was divided into two portions at the extreme end, the northern half curving very sharply upwards as in the figure, and separated from the southern branch by a semicircular space,

Orbit of The Great C[...]T.
obtained by a graphi[...]
and showing the obs[...]
taken about the tim[...]

[...]23 G.M.T.
[...]53′
[...]5·24″
[...]35·9″
[...]0080



M_1	Melbourne	Sept.r	15th...
M_2	„		16...
E_1	Ealing		16...
E_2	„		17·0
Ca_1	Cape		17...
D	Dunecht		17...
Co_1	Coimbra		18...
S	Sydney		18...
Ca_2	Cape		18...
Co_2	Coimbra		19...
Cor	Cordoba		19...
W	Washington		19...

One tenth part of Sun's r[...]

[...]nrose.

Spottiswoode & [...] Lith London

the general form of the tail being very similar to the Greek character γ. The southern side still remained the brightest.

Nov. 14, $17^h\ 30^m$.—The nucleus: the two concentrations of light were smaller, more elongated, and much closer together than when last observed. It was only through the definition being exceptionally good that the division could be seen. The whole nucleus was greatly changed, being much narrower and longer than on the 8th inst.

The Orbit of the Great Comet (b) 1882. By F. C. Penrose.

I have obtained by graphical means the elements given below. They are based on

(1) A meridian observation at Washington Sept. 21.
(2) Observations at Rome and Palermo Oct. 1.
(3) Rome, Palermo, Lund, and Athens Oct. 11.
And corrected by Cambridge University Nov. 26.

T	Sept. 17·223
Long. of ☊	345° 53′ 0″
i	38 5 24
π − ☊	69 35 9
Distance	[7·90309]

The orbit not being distinguishable from a parabola.

The places observed before perihelion do not exactly fit these elements, but would do so if the axis of the parabola be changed about 2° in its own plane. I have not succeeded in finding an orbit with an undeflected axis which would give a good account of the observations taken both before and after perihelion.

The accompanying plate shows the positions observed within about three days of the perihelion as reduced to the node and inclination given above.

It will be seen that the parabola threads its way amongst those taken after perihelion very satisfactorily.

I should add that the graphical work in itself appears to me capable of bringing out an approximation within ten minutes of arc of the finally concluded elements; and that may, I think, be taken as about the limit, unless a very large and inconvenient scale be adopted. The remaining work is done by adjusting the differences numerically.

The observations were corrected for parallax and aberration; and I found that near the perihelion even the graphical work in this orbit was affected very sensibly by these adjustments.

1882, Jan. 12.

Note on William Ball's Observations of Saturn. By Prof. J. C. Adams, M.A., F.R.S.

In No. 9 of vol. i. of the *Philosophical Transactions*, a brief account is given of an observation of *Saturn* made on Oct. 13, 1665, at 6 o'clock, by William Ball, at Mamhead, near Exeter, and it is suggested that the appearance presented by the planet may perhaps be caused by its being surrounded by *two* rings instead of *one*.

This account has recently given rise to considerable discussion; and there are some difficulties connected with it which do not appear to have been satisfactorily cleared up. In a few copies of the volume this account is illustrated by a figure, in which the external boundary of the ring, instead of being of a regular elliptical form, has two blunt notches or indentations at the extremities of the minor axis. The plate containing this figure, however, is wanting in by far the larger number of the copies.

Now, I think, it may be safely asserted that no telescope, capable of showing *Saturn's* ring at all, ever exhibited it in this extraordinary form, and therefore if the above figure faithfully represents William Ball's drawing, he was either a very inaccurate and careless observer, or he must have been provided with very inadequate instrumental means.

On the other hand, we have ample proof that he was a careful and assiduous observer, that in particular he made a long series of observations of *Saturn*, and that these were made with instruments not much inferior to those employed by Huyghens himself in similar observations.

It is well known that Huyghens's discovery of the true nature of the appendage to *Saturn*, which had so puzzled Galileo and others, was contested by Father Fabri at Rome, who wrote under the name of "Eustacius de Divinis."

Huyghens replied to Fabri's objections in a tract which appeared in 1660, entitled *Brevis Assertio Systematis Saturnii sui*, and which is contained in the third volume of his collected works.

In this tract he repeatedly appeals to Ball's observations in England in confirmation of his own. It is clear that Huyghens was in possession of drawings by Ball which represented the various appearances presented by the planet during the four years from 1656 to 1659 inclusive, and that he had carefully compared them with those which he had himself taken during the same interval. After mentioning the dark band which he had observed on the disk of *Saturn* at times when the remainder of the ring was invisible, he quotes a letter from Dr. Wallis, dated Dec. 22, 1658, in which reference is made to an earlier letter dated May 29, 1656, wherein Dr. Wallis had mentioned this band as having been observed by Ball, and had inquired whether his correspondent had likewise perceived it. Huyghens goes on to say that from Feb. 5, 1656, to July 2, when the planet appeared round

and without ansæ, this band or dark shading was observed by Ball to cross the centre of the disk, as shown in his drawing, exactly as in Huyghens's own figure.

Afterwards, when the ansæ had re-appeared, the band was seen with more difficulty, and its position was less accurately laid down in Ball's drawing. From Nov. 5, 1656, to July 9, 1657, when the oblong arms of *Saturn* were seen apparently united to the disk, Ball gives a figure quite similar to that of Huyghens, except that he makes the arms a little thicker.

Again, from Nov. 9, 1657, to June 7, 1658, when the arms were more open, Ball's figure is exactly similar to Huyghens's, except a slight difference in the position of the obscure zone or belt.

Also, finally, the same remark applies to the figure of the planet from Jan. 3, 1659, to June 17 of the same year, when the ansæ were a little more widely opened.

Having made these comparisons between Ball's drawings of the planet and his own, Huyghens remarks that Ball was unacquainted with his hypothesis* (respecting the ring), and therefore could not be supposed to be biased by it, while he himself would not dare to represent the phenomena otherwise than they really were, since, if he did, he might at once be contradicted by the English observer.

This judgment of so competent an authority as Huyghens, made while he had before him all the materials for forming it, left no doubt on my mind as to the merit of Ball's observations.

In order to see whether any further light could be thrown on the subject, I have recently taken an opportunity of consulting the MSS. preserved in the archives of the Royal Society.

Among them I find there is a letter in William Ball's own hand, dated April 14, 1666, in which he makes reference to his observations of *Saturn*, although the greater part of the letter relates to other subjects. He mentions that the observations were made partly with a telescope thirty-eight feet in length, having a double eye-glass, and partly with another telescope twelve feet in length. In the postscript to this letter he gives a small sketch of *Saturn* as it appeared at that time (1666), and he mentions that the same appearance was presented by the planet in 1664. In this figure the external boundary of the ring has the form of a regular oval, without any notches or other irregularities.

No allusion is made to the very different appearance which, if the figure in the *Philosophical Transactions* is authentic, the planet must have presented in 1665.

It should be understood that the paper in the *Philosophical Transactions* which is now in question was not written by Ball himself. It contains, however, a quotation from a letter of Ball to a friend (probably Sir R. Moray), and in what appears to be

* Huyghens's *Systema Saturnium* only appeared in 1659.

the last clause of this quotation, the figure is said to be "a little hollow above and below." I cannot help thinking that this clause has been added or altered in some way to correspond with the given figure. The letter of Ball on which this paper was founded is not in the archives; but there is preserved, not a drawing, but a paper cutting, representing the planet and its ring, which is no doubt the original of the figure engraved in the *Transactions*.

The defect in the paper cutting probably originated in the following way. In order to make the cutting, the paper was first folded twice in directions at right angles to each other, so that only a quadrant of the ellipse had to be cut.

The cut started rightly in a direction perpendicular to the major axis, but through want of care, when the cut reached the minor axis, its direction formed a slightly obtuse angle with that axis instead of being perpendicular to it.

Consequently, when the paper was unfolded, shallow notches or depressions appeared at the extremities of the minor axis.

I imagine that the account in the *Philosophical Transactions* was written by some one inexperienced in astronomical observations, who took for granted that the figure was correct. The mistake being soon discovered, the plate which contained the erroneous figure of *Saturn*, together with two other figures relating to different subjects, was cancelled, and thus its appearance in only a few of the copies is accounted for. The other figures on the cancelled plate were repeated in a new plate which accompanied No. 24 in the same volume of the *Transactions*.

In Lowthorp's abridged edition of the *Transactions* the figure of *Saturn* has been corrected.

I find no evidence that Ball, any more than Huyghens, had noticed any indication of a division in the ring.

It may be interesting to give the original text of the passages of Huyghens's *Brevis Assertio Systematis Saturnii sui*, in which reference is made to Ball's observations.

The citations are taken from the third volume of Huyghens's *Opera Varia*, edited by 'S Gravesande, and published at Leyden in 1724.

"Credo et fasciam nigricantem in *Saturni* disco, liquido sibi conspici dixisset Eustacius, ni Fabrio visum fuisset eam nimium hypothesi meæ annullari favere. Cum autem ne optimis quidem suis perspicillis eam cerni affirmet, hinc quoque quanto illa meis deteriora sint perspicuum sit. Nam ne mihi phenomenon illud confictum credatur, idem et in Anglia pridem observari cœpisse sciendum est; et liquet ex literis viri clar. Joh. Wallisii, Oxonia ad me datis 22 Dec. 1658, quibus inter alia hæc scribit. *Monebam etiam iisdem literis* (nempe *datis* 29 *Maji* 1656) *de Saturni fascia quam jam ante observaverat D. Ball, et sciscitabar num tu eandem conspexeras*, &c. Eam porro fasciam à 5 Feb. 1656 ad 2 Jul., quo tempore rotundus *Saturnus* absque ansis apparuit, medium planetæ discum secare D. Ball adnotavit, ut in schemate ad me misso expressa est. Atque ita mihi quoque

fuerat eo tempore observata, ut cernitur pag. 544 *Systematis Saturnii*, quam figuram hic repeto. Postmodum tamen renatis *Saturni* ansis cum difficillimè conspici eadem fascia cœpisset, minus rectè quoque a D. Ball, quantum ad situm attinet, depicta est. At in mearum observationum adversariis, die 26 Nov. 1656, et alias adscriptum invenio, lineam obscuram fuisse evidentissimam, eo nempe positu, qui pag. 545 *System. Saturnii* memoratur."—Pp. 624, 625.

. . . .

"Non ægre nunc fidem habitum iri spero, tum mihi tum Anglis simul observatoribus, qui anno 1657 oblonga *Saturni* brachia disco utrinque conjuncta spectavimus, qualia exhibet figura *Systematis* mei pag. 545, quam hic repono; non autem binorum orbiculorum formâ a medio disco disjunctorum, ut Eustacius se illa eodem tempore vidisse dejerat. Adderem hic schema quod mihi à D. Ball, supra memorato, advenit, nisi planè simile esset huic nostro, hoc uno tantillum duntaxat abludens, quod brachia illa ubique paullo crassiora ille referat.

"Eam vero formam a 5 Nov. 1656 ad 9 Jul. 1657 sibi apparuisse scribit. Apertis autem brachiis, qualis pag. 547 *Systematis* mei et hic representatur, talem à 9 Nov. 1657 ad 7 Jun. 1658, idem observator depingit, simillima prorsus figura, nisi quod ad positum zonæ obscuræ attinet, de quo dixi suprà. Ac denique à 3 Jan. 1659 ad 17 Jun. ejusdem anni, ansis paulo latius adhuc apertis. Et hæc quidem ille, ignarus adhuc meæ hypotheseos, ne ob præconceptam opinionem aliquid indulsisse sibi existimetur. Neque ego aliter quam se revera habent referre auderem, cum redarguere me, si fallam, autori observationum in promptu sit."—P. 626.

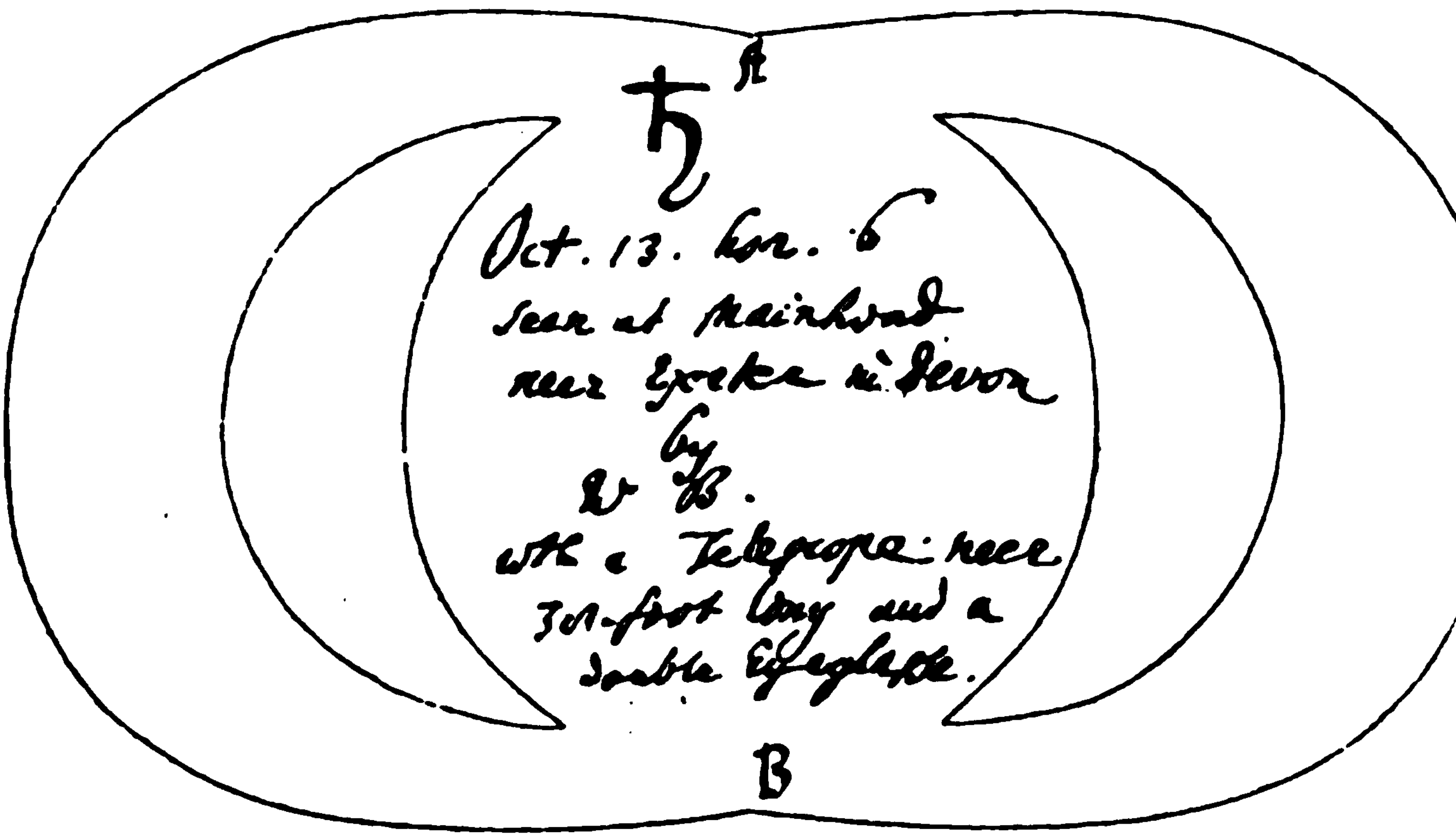
The following extract comprises all that is material in the Paper in the Philosophical *Transactions*:—

"This observation was made by Mr. William Ball, accompanied by his brother, Dr. Ball, October 13, 1665 at six of the Clock, at Mainhead near Exeter in Devonshire, with a very good Telescope near 38 foot long, and a double Eye-glass as the observer himself takes notice, adding, that he never saw that planet more distinct. The observation is represented by Fig. 3 concerning which, the Author saith in his letter to a friend, as follows, This appear'd to me the present figure of Saturn, somewhat otherwise, than I expected, thinking it would have been decreasing, but I found it full as ever, and a little hollow above and below. Whereupon the Person, to whom notice was sent hereof, examining this shape, hath by letters desired the worthy Author of the *System of this Planet*, that he would now attentively consider the present Figure of his Anses, or Ring, to see whether the appearance be to him, as in this Figure, and consequently whether he there meets with nothing that may make him think, that it is not *one* body of a circular Figure, that embraces his Disk, but *two*."

From this it is clear that the suggestion of *two* rings was made, not by Ball himself, but by his anonymous correspondent.

By the kind permission of the President and Council of the Royal Society, I am enabled to make the following extracts from two letters in William Ball's own hand, and likewise to give exact representations of the form of the paper-cutting, and of Ball's small sketch of *Saturn*, referred to in the foregoing Paper, both of which have been kindly copied for me by our Assistant-Secretary, Mr. Wesley.

The annexed figure shows the form of the paper-cutting.



The writing on the cutting appears to be in Oldenburg's hand.

The first letter is dated Mamhead, April 14, 1666, and is probably addressed to Oldenburg.

"I have seen ♄ two mornings this year (with a 12 foot glasse the longest I can use at this time with convenience) and find the figure the same as it was in -64. What his figure was last autumne (by mee observed with 38 foot glasse much better than that at Gresham Colledge) I suppose S^r. R. Moray hath communicated. I could not have a second sight, straining very much for that one, for the shadow of the body on his ring I doe not well understand the meaning but I suppose I saw the same thing; for I never had a clearer sight of him in any glasse I ever looked in, one thing I can boast of, sc. I am not prejudiced with any conceit of hypothesis which doth commonly send all observations to favour one side and soe there must bee a little added or diminished as the designe requires," &c. &c.

In a postscript is the following, with the little sketch:—

"I saw ♄ this morn. at 4 a clock with 12 foot glasse and judge him the same figure as in -64—that is just ovall with two black spotts and I thinke a faint shadow of a belt which I have alwaies seene, but will not be peremptory in itt."

The second letter is dated "Mamhead ♄ September 15,-66," and is addressed "For Sir Robert Moray K[t] at Whitehall, These."

"I designe to send you all the figures of ♄. I promised them my L[d] Brounker and hee was pleased most kindly to accept itt but I (like any thing you please to call mee bad enough) have hitherto shamfully failed, as alsoe of an account of husbandry to Mr. Oldenburg. I am still gazing at the starrs though to very little purpose more then to keep my eyes in use,"&c. &c.

It will be noticed that the passage in Ball's first letter in which he claims to be unbiased by any hypothesis, agrees with the statement of Huyghens respecting him.

The passage in the same letter, "for the shadow of the body on his ring I doe not well understand the meaning but I suppose I saw the same thing," I conjecture to refer to an attempted explanation by Huyghens, or some other astronomer, of the phenomenon observed by Ball, by attributing it to the shadow of the body of the planet cast on his ring.

It is plain that such an explanation would not be applicable, if similar depressions had been observed at the two extremities of the minor axis of the ring.

Observations of Jupiter. By W. F. Denning.

The southern equatorial belt of *Jupiter* is by far the most conspicuous feature at present visible on the surface of the planet. This belt is double, and can be readily traced as two perfectly parallel bands in all parts of the circumference except in the region immediately N. of the great red spot where it is connected at the *p.* and *f.* ends of the spot. At these points the southernmost half of the belt slopes abruptly to the N., and runs into the northernmost half, so that the great red spot now apparently lies south of a great cavity in the configuration of the dusky equatorial belts.

In the immediate region of the planet's equator, numerous dark spots and irregular patches appear from time to time, and it is important that the rotation period of these objects should be determined. They usually lie on the equatorial border of the great S. belt, and in approximately the same latitude as the permanent white spots to which so much attention has lately been given. On Oct. 26, 1882, just before daylight, I noticed a very conspicuous marking of this character slightly preceding the white equatorial spot. I re-observed this peculiar dark spot on many subsequent occasions, and recorded its times of transit across the central meridian of *Jupiter* relatively to the well-known white spot. The results show that the two objects have a common rotation period, whence we may assume that all the various markings both light and dark along the equator

participate in a swift movement past the red spot. The following were the estimated times of transit recorded between Nov. 1 and Nov. 26, after which cloudy weather and other circumstances prevented a continuation of the observations :—

1882.	Equatorial Dark Spot central.	Equatorial White Spot central.	Dark Spot precedes White Spot.
	h m	h m	m
Nov. 1	17 22	17 40	18
3	18 33	18 50	17
4	14 7	14 25	18
5	9 48	10 1	13
8	16 33	16 48	15
9	12 13	12 28	15
10	17 48	18 3	15
26	7 30	7 45	15
26	17 24	17 37	13

The interval separating the spots decreased from 18^m to 13^m during the 25 days, but considering the approximate nature of the observations and the fact that the estimated intervals were identical on Nov. 5 and 26, it is certain that the difference (if any) in the rotation periods of the two objects must have been so small as to escape certain detection. It therefore appears that the frequent obscuration of the white equatorial spots are not originated by a swifter motion of the dark spots in the same latitude, for both objects are seemingly influenced by the same current. This accords with Prof. Hough's observations in 1881; he found that the drift of the dark matter in the equatorial regions was essentially the same as that of the white spots. While, however, a uniform velocity appears to influence these markings on the equatorial half of the great Southern belt, causing them to become displaced, relatively to the position of the red spot, to the extent of 8° of longitude daily, it is certain that the southernmost half of the belt remains stationary with reference to the red spot, for during the three oppositions of 1880, '81, and '82 the junction of the belt N. of the *f* end of the red spot has retained a fixed position.

In the region N. of the planet's equator many changes have occurred during the last few months. A considerable number of dusky patches have made their appearance, and a few brilliant white spots are visible where, in 1880, the planet's dark N. belt was very conspicuous. In November I observed the return of a brilliant spot N. of the equator, and found that it moved perceptibly slower than the somewhat similar and evidently more permanent spot slightly S. of the equator. The following were the times :—

1882.	N. equatorial White Spot central. h m	S. equatorial White Spot central. h m		m
Oct. 30	15 56	16 22	N. spot precedes S.	26
Nov. 1	17 22	17 40	" "	18
3	18 41	18 50	" "	9
4	14 23	14 25	" "	2
5	10 4	10 1	" follows S.	3
8	17 1	16 48	" "	13
9	12 39	12 28	" "	11
10	18 22	18 3	" "	19
11	14 5	13 43	" "	22
19	9 25	8 37	" "	48
26	18 48	17 37	" "	71

The spot N. of the equator lost 97 minutes in 27 days, so that (the period of the S. spot being $9^h\ 50^m\ 7^s$) its rotation was performed in about $9^h\ 51^m\ 40^s$, or 4 minutes less than the red spot and $1\frac{1}{2}$ minutes greater than that of the white spot S. of the equator. On Nov. 26 the N. spot had become extremely faint and could not be followed any longer, yet early in November it was far brighter than the S. spot, and formed a very conspicuous feature upon the planet.

It is evident from these and many other recent observations of markings included within the equatorial belts, and of those situated further towards the poles, that the rotation periods vary in a very irregular and unaccountable manner. They do not seem to be affected or controlled by any law depending upon their latitudinal distribution. It appears certain, however, that the markings on and skirting the planet's equator *generally* move with far greater velocity than those outside the equatorial belts. This conclusion is warranted by the independent results of several observers, but it is nevertheless liable to great exceptions. In the autumn and winter of 1880 an eruption of dark spots occurred on a belt approximately situated 25° N. of the planet's equator. These spots were first seen by Mr. F. C. Dennett at Southampton, on Oct. 17, and afterwards very generally observed, when it was found that they not only increased in numbers and size, but showed a rapid motion relatively to the red spot. Their rotation period was about $9^h\ 48^m$, and they completed a revolution of *Jupiter* relatively to the red spot in about 32 days. These markings moved with greater velocity than any others, the periods of which have ever been determined, and the fact is very important as they were so far removed from the equator.

Prof. Hough, in his valuable summary of observations at Chicago, says: "The observations of the small white spots during 1880 and 1881 prove that the whole surface of the planet outside the margin of the equatorial belt rotates with nearly the

same rate;" and, "From observations on the small white spots, as well as on dark markings near the equator, it is probable that the matter in the equatorial regions constantly drifts in the direction of the planet's rotation; and it seems probable that the rate of this drift depends on the latitude." The dark spots seen in 1880 far N. of the equator, by many English observers, apparently furnish a negative to this conclusion. It is possible, however, that the small white spots outside the equatorial zone move slower than the dark markings referred to. It is evident that the different velocities of the various spots offer a very complex problem for solution. It may be that though these velocities follow no law dependent upon distance from the equator, they may each be special to the zones in which they occur. Or they may possibly be accounted for on the thesis that the planet is enveloped in a series of dense atmospheric layers or shells, each of which, according to height, manifests a different rate of motion, which becomes revealed either by temporary disruption or partial decadence of the outer envelopes. There is, probably also vast differences of temperature in the various markings observed, and this may originate another element of disturbance. In any case, we may be assured that all the varieties of spots and streaks observed so persistently and numerously upon the planet are the phenomena of his dense atmosphere and not objects of stability upon his actual surface, which seems to be entirely shrouded from our scrutiny by masses of heated vapour which are woven into parallel bands by the effects of a very rapid rotatory movement. The further telescopic study of these remarkable markings cannot fail to prove of considerable interest, and may perhaps lead to the partial elucidation of what now appears to present difficulties beyond explanation.

Bristol: 1883, *Jan.* 11.

Postscript, on a Communication made to the Royal Astronomical Society, in November last, on Stellar Photometry. By Professor C. Pritchard, D.D., F.R.S.

Since my last communication in November 1882, I have had an opportunity of examining another wedge of neutral-tinted glass constructed for Mr. Knott by Mr. Hilger. It has been scrupulously measured by the same photometrical process as that described in my paper already referred to. The instrument I find to be practically uniform in its action throughout its extent of 6 inches in length, but I have also furnished Mr. Knott with a table, theoretically exact, by means of which, from simple inspection, he may be able to reduce the graduated indications of the wedge to the difference of the magnitudes of any star whose light is just extinguished by the instrument. I need scarcely repeat that, although on different nights, the same star will be

extinguished at very perceptibly different parts of the wedge, the intervals of length between the points of extinction of the lights of two stars will be found to be sensibly the same on different nights. After the application of this photometer to many thousand measures, I can hardly conceive any photometrical process more simple either in the way of observation or in the subsequent reduction of the observations.

If this were all that I have to say on the subject, I should not be justified in at present occupying the valuable time of the Society's meeting. But in measuring photometrically Mr. Knott's wedge, I took the opportunity of still further testing its capacity, in respect of its capability of measuring the relative intensity of light of *different colours.*

I had already established the fact that the same thickness of wedge reduces the ratio of the incident and emergent lights in the same degree, whatever may be the colour of the light. But it seemed to me to be desirable to inquire further, whether two equal lights of two different colours would be extinguished at the same point of the wedge. This experiment seemed crucial as to the applicability of the photometer to stars of different colours, and especially of double stars of this description. Accordingly, I arranged an apparatus, consisting of a rhomb of calcspar, a uniform plate of selenite, and a Nicol prism, and in this way I obtained two coloured images of a small rectangular aperture illuminated with white light from the sky, the apparatus being so arranged that the two coloured images must possess theoretically the same intensity. The two coloured lights—in this instance, yellow and its complementary green—were extinguished at practically the same point of the wedge. This experiment, which was verified by no less than four experienced observers, appears to establish the applicability of the instrument to stellar photometry irrespective of the colours of individual stars. In this inquiry I was greatly assisted by the experience and personal aid of H. B. Dixon, Esq., of Trinity College, whose photometrical researches while Secretary to a Royal Commission on the subject of standard candles and the quality of illumination by coal gas, are well known.

Notwithstanding the theoretical equality of the two complementary coloured lights, to the unaided eye of all the observers the yellow light appeared to be the brighter of the two lights: probably the yellow light would have been estimated at half a magnitude brighter than the green; and this fact, I think, explains the circumstance that Prof. Pickering's measures of the relative magnitude of the two components of *β Cygni* assign a greater degree of brightness to the larger yellow component compared with that of the smaller and blue component than is assigned to it in the Oxford photometry. The measures of relative brilliancy of the two components give the following results (*Monthly Notices*, vol. xliii. p. 5):—

Harvard College, diff. of magnitude		2·14
Oxford	„	1·74
Oxford repeated (Nov. 6)	„	1·82

Having reason to place great reliance on Professor Pickering's photometry, I directed the re-observation of the stars. The result (given above) confirmed the Oxford measure, and nothing remained for me but to agree to differ from the Harvard result. I think the trifling discrepancy, for after all it is but trifling, admits now of a very satisfactory explanation. The Harvard photometer is on the principle of applying the judgment of the eye to the equality of light; the Oxford method relies on the judgment of the eye as to the point of extinction of a light. Each is valuable in its way, but as at present advised (and with special reference to the experiment just mentioned) I am inclined to place a greater reliance on the latter method in the case of photometry of double stars of *different* colours.

I will close this note by stating that the photometry of the brighter stars from the Pole to the Equator is now completed, and that before the reading of this note to the Society I shall be on my way to Cairo for the purpose of instituting some inquiries respecting the atmospheric and climatic effects on the absolute brilliancy of stars, which appear to me to be essential to the completion of this photometric research.

Reduction of Latitude and Logarithm of the Earth's Radius with Col. Clarke's Value of the Earth's Compression. By E. J. Stone, M.A., F.R.S.

The semi-diameters of the spheroid, which best represents the Earth's surface, determined by Col. Clarke, differ considerably from those found by Airy and Bessel.

The following are the results for the Equatorial and Polar semi-diameters expressed in English feet:—

	a	b	$a:b$
Airy ...	20923713	20853810	299·33 : 298·33
Bessel ...	20923600	20853656	299·15 : 298·15
Clarke ...	20926202	20854895	293·465 : 292·465

The two first results agree in a very remarkable manner; but to a great extent they were deduced from a discussion of the same data.

A large mass of observations, bearing on the question of the figure of the Earth, have recently been made available, and Col. Clarke has attacked the question with far more extensive materials than were available to Airy or Bessel in their discussions. I presume therefore we must accept Col. Clarke's

results as more accurate than those of Airy and Bessel, and that Col. Clarke's value of the ratio $a : b$ ought to be adopted for use in our calculations.

I have therefore formed a table, with Col. Clarke's value of the ratio $a : b$, of the *reductions* from the astronomical or geographical latitudes to the geocentric latitude, and also the *logarithms* of the ratios of the radii to the equatorial semi-diameter.

The formulæ from which the computations have been made are as follows:—

$$e^2 = 1 - \frac{b^2}{a^2} \qquad \epsilon = \frac{e^2}{2} + \left(\frac{e^2}{2}\right)^2 + \left(\frac{e^2}{2}\right)^3. \qquad \text{M} = \text{mantissa of base 10.}$$

ϕ, ϕ' the astronomical and geocentric latitudes.

$$\phi' = \phi - \frac{\epsilon . \sin 2\phi}{\sin 1''} + \frac{\epsilon^2}{2} \cdot \frac{\sin 4\phi}{\sin 1''} - \frac{\epsilon^3}{3} \cdot \frac{\sin 6\phi}{\sin 1''},$$

$$\log \frac{r}{a} = \text{M} \left\{ \left(-\frac{e^2}{4} - \frac{e^4}{32} + \frac{e^6}{96} \right) + \cos 2\phi \left(+ \frac{e^2}{4} + \frac{e^4}{8} + \frac{3}{64} e^6 \right) \right.$$
$$\left. + \cos 4\phi \left(-\frac{3}{32} e^4 - \frac{3}{32} e^6 \right) + \cos 6 \left(\frac{7}{2} e^6 \right) \right\}$$

The terms sin 6ϕ and cos 6ϕ are insensible to the order of approximation adopted.

ϕ ° ′	$\phi - \phi'$ ′ ″	Diff. ″	log. ρ	Diff.
0 0	0 0·00	24·49	0·0000000	3
1 0	0 24·49	24·46	9·9999997	14
2 0	0 48·95	24·39	9983	22
3 0	1 13·34	24·31	9961	31
4 0	1 37·65	24·20	9930	40
5 0	2 1·85	24·04	9890	49
6 0	2 25·89	23·87	9·9999841	58
7 0	2 49·76	23·67	9783	66
8 0	3 13·43	23·43	9717	75
9 0	3 36·86	23·17	9642	83
10 0	4 0·03	22·88	9559	92
11 0	4 22·91	22·56	9467	100
12 0	4 45·47	22·22	9·9999367	109
13 0	5 7·69	21·85	9258	116
14 0	5 29·54	21·45	9142	124
15 0	5 50·99	21·02	9018	133
16 0	6 12·01	20·58	8885	139
17 0	6 32·59	20·10	8746	147

ϕ		$\phi-\phi'$		Diff.	log. ρ	Diff.
°	′	′	″	″		
18	0	6	52·69	19·60	9·9998599	155
19	0	7	12·29	19·08	8444	161
20	0	7	31·37	18·54	8283	169
21	0	7	49·91	17·97	8114	175
22	0	8	7·88	17·37	7939	182
23	0	8	25·25	16·77	7757	187
24	0	8	42·02	16·13	9·9997570	194
25	0	8	58·15	15·49	7376	200
26	0	9	13·64	14·81	7176	206
27	0	9	28·45	14·12	6970	210
28	0	9	42·57	13·42	6760	216
29	0	9	55·99	12·70	6544	221
30	0	10	8·69	2·04	9·9996323	37
	10		10·73	2·03	6286	37
	20		12·76	2·00	6249	38
	30		14·76	1·98	6211	37
	40		16·74	1·97	6174	38
	50		18·71	1·94	6136	38
31	0	10	20·65	1·92	9·9996098	38
	10		22·57	1·90	6060	38
	20		24·47	1·88	6022	38
	30		26·35	1·85	5984	38
	40		28·20	1·84	5946	39
	50		30·04	1·81	5907	38
32	0	10	31·85	1·80	9·9995869	39
	10		33·65	1·77	5830	39
	20		35·42	1·75	5791	39
	30		37·17	1·73	5752	38
	40		38·90	1·71	5714	39
	50		40·61	1·68	5675	
33	0	10	42·29	1·67	9·9995635	39
	10		43·96	1·64	5596	39
	20		45·60	1·62	5557	40
	30		47·22	1·60	5517	39
	40		48·82	1·58	5478	40
	50		50·40	1·55	5438	40

ϕ	$\phi-\phi'$	Diff.	log. ρ	Diff.
° ′	′ ″	″		
34 0	10 51·95	1·54	9·9995398	40
10	53·49	1·51	5358	40
20	55·00	1·49	5318	40
30	56·49	1·46	5278	40
40	57·95	1·45	5238	40
50	59·40	1·42	5198	41
35 0	11 0·82	1·40	9·9995157	40
10	2·22	1·38	5117	41
20	3·60	1·36	5076	40
30	4·96	1·33	5036	41
40	6·29	1·31	4995	41
50	7·60	1·29	4954	40
36 0	11 8·89	1·27	9·9994914	41
10	10·16	1·24	4873	41
20	11·40	1·22	4832	41
30	12·62	1·20	4791	41
40	13·82	1·17	4750	42
50	14·99	1·15	4708	41
37 0	11 16·14	1·13	9·9994667	41
10	17·27	1·11	4626	42
20	18·38	1·08	4584	41
30	19·46	1·06	4543	42
40	20·52	1·04	4501	42
50	21·56	1·02	4459	41
38 0	11 22·58	0·99	9·9994418	42
10	23·57	·97	4376	42
20	24·54	·94	4334	42
30	25·48	·93	4292	42
40	26·41	·90	4250	42
50	27·31	·87	4208	42
39 0	11 28·18	0·85	9·9994166	42
10	29·03	·83	4124	42
20	29·86	·81	4082	42
30	30·67	·78	4040	43
40	31·45	·76	3997	42
50	32·21	·74	3955	42

ϕ	$\phi-\phi'$	Diff.	log. ρ	Diff.
° ′	′ ″	″		
40 0	11 32·95	0·71	9·9993913	43
10	33·66	·69	3870	42
20	34·35	·67	3828	43
30	35·02	·64	3785	42
40	35·66	·62	3743	43
50	36·28	·59	3700	42
41 0	11 36·87	0·57	9·9993658	43
10	37·44	·55	3615	43
20	37·99	·53	3527	42
30	38·52	·50	3530	43
40	39·02	·47	3487	43
50	39·49	·46	3444	43
42 0	11 39·95	0·43	9·9993401	43
10	40·38	·40	3358	43
20	40·78	·39	3315	42
30	41·17	·36	3273	43
40	41·53	·33	3230	43
50	41·86	·31	3187	43
43 0	11 42·17	0·29	9·9993144	43
10	42·46	·26	3101	43
20	42·72	·24	3058	43
30	42·96	·22	3015	43
40	43·18	·19	2972	43
50	43·37	·17	2929	44
44 0	11 43·54	0·15	9·9992885	43
10	43·69	·12	2842	43
20	43·81	·10	2799	43
30	43·91	·07	2756	43
40	43·98	·05	2713	43
50	44·03	·02	2670	43
45 0	11 44·05	0·01	9·9992627	43
10	44·06	·03	2584	43
20	44·03	·04	2541	44
30	43·99	·07	2497	43
40	43·92	·09	2454	43
50	43·83	·12	2411	43

φ	φ−φ′	Diff.	log. ρ	Diff.
° ′	′ ″	″		
46 0	11 43·71	0·14	9·9992368	43
10	43·57	·17	2325	43
20	43·40	·18	2282	43
30	43·22	·22	2239	43
40	43·00	·23	2196	43
50	42·77	·26	2153	43
47 0	11 42·51	0·29	9·9992110	43
10	42·22	·30	2067	43
20	41·92	·34	2024	43
30	41·58	·35	1981	43
40	41·23	·38	1938	43
50	40·85	·40	1895	43
48 0	11 40·45	0·43	9·9991852	43
10	40·02	·45	1809	43
20	39·57	·47	1766	43
30	39·10	·50	1723	43
40	38·60	·52	1680	43
50	38·08	·55	1637	43
49 0	11 37·53	0·56	9·9991594	42
10	36·97	·60	1552	43
20	36·37	·61	1509	43
30	35·76	·64	1466	42
40	35·12	·66	1424	43
50	34·46	·69	1381	42
50 0	11 33·77	0·71	9·9991339	43
10	33·06	·73	1296	42
20	32·33	·76	1254	43
30	31·57	·78	1211	42
40	30·79	·80	1169	43
50	29·99	·83	1126	42
51 0	11 29·16	0·85	9·9991084	42
10	28·31	·88	1042	42
20	27·43	·89	1000	42
30	26·54	·92	0958	42
40	25·62	·95	0916	42
50	24·67	·96	0874	42

ϕ	$\phi-\phi'$	Diff.	log. ρ	Diff.
° ′	′ ″	″		
52 0	11 23·71	1·00	9·9990832	42
10	22·71	1·01	0790	42
20	21·70	1·03	0748	42
30	20·67	1·06	0706	42
40	19·61	1·09	0664	41
50	18·52	1·10	0623	42
53 0	11 17·42	1·13	9·9990581	42
10	16·29	1·15	0539	41
20	15·14	1·18	0498	42
30	13·96	1·20	0456	41
40	12·76	1·21	0415	41
50	11·55	1·25	0374	41
54 0	11 10·30	1·26	9·9990333	41
10	9·04	1·29	0292	41
20	7·75	1·31	0251	41
30	6·44	1·34	0210	41
40	5·10	1·35	0169	41
50	3·75	1·38	0128	41
55 0	11 2·37	1·40	9·9990087	40
10	11 0·97	1·43	0047	41
20	10 59·54	1·44	0006	40
30	58·10	1·47	9·9989966	41
40	56·63	1·49	9925	40
50	55·14	1·52	9885	40
56 0	10 53·62	1·53	9·9989845	40
10	52·09	1·56	9805	40
20	50·53	1·58	9765	40
30	48·95	1·60	9725	40
40	47·35	1·63	9685	40
50	45·72	1·64	9645	39
57 0	10 44·08	1·67	9·9989606	40
10	42·41	1·69	9566	39
20	40·72	1·71	9527	39
30	39·01	1·73	9488	40
40	37·28	1·76	9448	39
50	35·52	1·77	9409	39

φ	φ−φ′	Diff.	log. ρ	Diff.
° ′	′ ″	″		
58 0	10 33·75	1·80	9·9989370	39
10	31·95	1·82	9331	38
20	30·13	1·84	9293	39
30	28·29	1·86	9254	38
40	26·43	1·89	9216	39
50	24·54	1·90	9177	38
59 0	10 22·64	1·93	9·9989139	38
10	20·71	1·95	9101	38
20	18·76	1·96	9063	38
30	16·80	1·99	9025	38
40	14·81	2·01	8987	38
50	12·80	2·03	8949	38
60 0	10 10·77	12·62	9·9988911	223
61 0	9 58·15	13·35	8688	218
62 0	9 44·80	14·06	8470	213
63 0	9 30·74	14·77	8257	208
64 0	9 15·97	15·45	8049	202
65 0	9 0·52	16·11	7847	197
66 0	8 44·41	16·76	9·9987650	190
67 0	8 27·65	17·37	7460	184
68 0	8 10·28	17·98	7276	178
69 0	7 52·30	18·56	7098	171
70 0	7 33·74	19·11	6927	164
71 0	7 14·63	19·65	6763	157
72 0	6 54·98	20·16	9·9986606	150
73 0	6 34·82	20·65	6456	142
74 0	6 14·17	21·10	6314	134
75 0	5 53·07	21·54	6180	127
76 0	5 31·53	21·95	6053	119
77 0	5 9·58	22·32	5934	110
78 0	4 47·26	22·68	9·9985824	102
79 0	4 24·58	23·01	5722	93
80 0	4 1·57	23·30	5629	86
81 0	3 38·27	23·57	5543	76
82 0	3 14·70	23·81	5467	68
83 0	2 50·89	24·02	5399	58

ϕ	$\phi-\phi'$	Diff.	log. ρ	Diff.
° ′	′ ″	″		
84 0	2 26·87		9·9985341	
		24·20		50
85 0	2 2·67		5291	
		24·35		41
86 0	1 38·32		5250	
		24·48		32
87 0	1 13·84		5218	
		24·56		23
88 0	0 49·28		5195	
		24·62		13
89 0	0 24·66		5182	
		24·66		5
90 0	0 0·00		5177	

Meteors and Meteorology. By Richard A Proctor.

It will be in the knowledge of most of the Fellows of this Society that Erman long since maintained a meteoric theory in explanation of the so-called "cold days" which occur in February, April, and May. He believed that the cold which on the average of a great number of years is found to characterise those days is due to the existence of meteoric streams between the Earth and the Sun. He even held that the cold of February is due to the August meteor system, whose ascending node would have about the same heliocentric longitude as the Earth has at the middle of the February cold spell; while in like manner he associated the cold days of May with the November meteors. We now know that this part of his theory is mistaken. The ascending nodes of those two important meteor systems lie in the right heliocentric longitude; but, unfortunately for the theory, both meteor systems cross the plane of the ecliptic ascendingly far outside the Earth's orbit, so that she may throw her shadow on the meteors of those systems, but cannot possibly be shadowed by them.

I have been in the habit of regarding Erman's theory as probably erroneous altogether, though noting that it would have to be accepted if any evidence were obtained showing the whole Earth, and not Europe only, to undergo these periodical refrigerations. Mr. Russell, Government Observer at Sydney, has recently published evidence which seems to go a great way towards proving that this really is the case. In Australia and in America, it would seem, the average temperature of the cold days is lower than it should be if the seasonal rise from January to July were steadily maintained. He also quotes evidence obtained in Galileo's time, which shows that the same peculiarity was recognised in Europe more than two centuries and a half ago. That sometimes the fall of temperature must have been very marked is shown by the existence of popular proverbial expressions, doggerel verses, and so forth, in reference to these cold spells.

It seems to me, then, that we must revert to the meteoric theory, recognising in the existence of meteoric systems between

the Earth and Sun the explanation of the average fall of temperature,* while in the incompleteness of meteoric rings we find explanation of the frequent absence of all fall of temperature at these times; and in the great wealth of that part of such systems which has been poetically called the gem of the meteor ring we find an explanation of the intense cold often felt on the ill-omened days, such cold as to justify what has been said of the three April "cold days"—

> The first of them is wan and weet,
> The second it is cold and sleet,
> The third it comes with sic a freeze
> As gars the birds stick to the trees.

It would be of interest, I believe, to many if at those places where underground temperature is noted the average and also the actual temperatures for the cold days could be noted during many successive years. If meteoric shadow is in question, it is probable that the meteor systems, or at least those parts which cast the shadow, are near the Sun. If so, there might be some slight but discernible change in the solar spectrum on those days. If (as I trust) Dr. Huggins has really succeeded in securing photographs of the solar corona with the Sun uneclipsed, and if (as I believe) the outer coronal radiations are meteoric, we may be able before long to obtain more definite information on this question. It may even perhaps be shown that more extended meteorological relations depend on meteoric systems near the Sun, and that Sun-spots may be relieved of part of the imputations cast on them as weather-breeders. We might even find in meteoric periodicity near the Sun the explanation of Sun-spots themselves.

The Aquariads of April 29 to May 3 (Tupman, No. 33). By W. F. Denning.

On April 30 and May 2–3, 1870, and again on April 29, 1871,† Col. Tupman observed a remarkably fine shower of meteors from points averaging $326° - 2\frac{1}{2}°$ near *α Aquarii*. The meteors were very brilliant, with streaks and long paths. This shower, being only visible for a short interval before sunrise, has received no good confirmation from subsequent observations. But it now appears that the recently published *Osservazioni di Stelle Cadenti fatte nelle stazioni Italiane durante gli anni* 1868, 1869 *e* 1870, in which are recorded the paths of 7602 shooting stars (chiefly

* It may be observed that in our almanacs no notice is taken of the peculiarity. It is treated as merely accidental, and the average temperatures are corrected (?) so as to rise and fall uniformly throughout the year. Buchan gives in his *Handy-book of Meteorology* a meteorological explanation which might hold but for Mr. Russell's evidence.

† There is some doubt as to the year in this case. In the B. A. Catalogue of Col. Tupman's observations it is given as 1871, but in the *Monthly Notices*, vol. xxxiii. p. 301, it is stated as 1869.

observed in 1870), that many of the meteors of Col. Tupman's shower were seen by the Italians, though the fact has previously escaped comment, as the observations have never been reduced. I have projected the apparent paths of 229 meteors in this catalogue recorded during the period from April 29 to May 6, 1870, between the hours of 13 and 15½, and find that at least 45 of these appear most unquestionably to have belonged to this shower of Aquariads, and the confirmation is important as being based on observations made simultaneously with those of Col. Tupman.

The radiant point of this stream, as I have derived it from this new source, is at $335° - 9°$, which is some 11° S.E. of the place determined by Col. Tupman. I projected the apparent paths both upon the star charts prepared by the B. A. Committee on Luminous Meteors and upon a celestial globe of 18 in. diameter. I adopted the latter plan as a means of finding the length of path traversed in each case. The average of 45 meteors (24 of which were seen on the morning of May 4, 1870) is $34°\cdot7$, which is much greater than the ordinary length of meteor tracks. Their brightness also appears to have been very exceptional, 1 being estimated = ♀, 2 = ♃, and 13 = first mag. stars. The mean length of 11 Aquariads registered by Col. Tupman on the morning of May 3, 1870, was $20°\cdot5$, which also far exceeds the average; and Mr. Corder, at Writtle, describes three of the meteors of this shower observed by him on the morning of May 4, 1878, as "remarkable for great length of path." These Aquariads are usually represented as swift, with bright streaks; and the inordinately long flights thus attributed to them by several different observers sufficiently prove them to have been directed from a radiant point very low on the horizon.

Giuseppe Zezioli, at Bergamo, recorded three Aquariads on the morning of May 3, 1868; and Mr. Corder has fixed the position of the radiant at $334° - 5°$ from six "fine long meteors," which he himself observed* before daybreak at the end of April and beginning of May. My own efforts to observe this shower have generally been frustrated either by clouded skies or moonlight. In 1880 it must, however, have become extremely feeble, for watching the eastern sky between $14^h\ 15^m$ and 15^h on May 2 I only saw two shooting stars, of which one was clearly an Aquariad.† It rose upwards in the W. region of *Pegasus*, and was therefore not far from the radiant point which from this single observation I judged to lie slightly to the E. of the position assigned by Mr. Corder.

It seems obvious from the reduction of the meteors seen in Italy in 1870 and from Mr. Corder's later observations that the radiant point of this brilliant shower is really situated to the S.E. of the place originally given by Col. Tupman. This may be easily settled by future observations if the display continues

* *Monthly Notices*, vol. xl. p. 135, radiant No. 23.

† *Observatory*, vol. iii. p. 449.

actively visible. Certainly on the morning on May 3, 1880, it was very feeble, and may now quite possibly have died out altogether. It should, however, be looked for with close attention during the next few years. The shower is a very important one, inasmuch as it agrees with the radiant point computed for Halley's Comet (1835, III.), whose nearest approach to the Earth's orbit occurs twelve days before reaching the descending node. Prof. Herschel gives the cometary radiant as $337° \pm 0°$ May 4,* and this falls significantly close to the meteoric radiant. The agreement, though striking, may of course be purely accidental, but there is no doubt this shower of meteors should be assiduously looked for with a view to determine the exact centre of divergence, and whether its activity has been sustained since the very rich display of 1870.

The following are the observed paths of 45 meteors registered by the Italians in 1870, and presumably belonging to this shower of Aquariads :—

Date and Hour. 1870.	Mag.	Observed Path From α δ	To α δ	Length of Path.	Appearance.	Observer.
April 29.						
h m						
13 27	1	337+54	151+53	85	V. slow ; streak	V.
14 32	2	195+74	164+41	36	Swift ; streak	V.
13 36	2	351+61	120+69	45	„	Gi.
April 30.						
15 20	3	182+58	163+41	21	V. swift	M.
15 20	4	182+58	165+46	16	„	M.
May 3.						
14 25	2	170+83	163+61	22	Swift ; streak	V.
14 40	3	20+64	68+73	19	Swift	V.
15 55	3	250+64	203+54	25	Slow	V.
14 52	3	319+11	312+37	27	Swift ; streak	Bz.
14 53	2	157+81	158+62	19	„	Ga.
14 55	3	327+17	317+41	25	Swift	Bz.
15 8	3	160+90	160+69	21	V. swift	Ba.
15 28	3	190+80	166+60	21	Swift	C.
14 15	1	3+39	28+50	21	Swift ; streak	I.
14 26	1	268+40	202+48	47	„	I.
14 26	4	202+56	178+47	18	Swift	I.
14 41	2	357+30	13+43	18	Swift ; streak	I.
15 5	♃	180+78	146+50	31	„	I.
15 36	3	349+60	29+73	20	Slow	I.

* B. A. Report on Luminous Meteors for 1875, pp. 229, 232. *Monthly Notices*, vol. xxxvi. p. 222, and vol. xxxviii. p. 379.

Date and Hour. 1870.	Mag.	Observed Path From α δ	To α δ	Length of Path.	Appearance.	Observer.
May 3.						
h m						
13 40	♀	359 + 31	121 + 58	88	V. slow	Z.
13 55	1	357 + 37	7 + 47	12	Swift	Z.
13 57	1	294 + 11	265 + 32	34	V. swift	Z.
14 43	1	322 + 8	313 + 17	12	Swift	Z.
13 8	3	8 + 56	26 + 63	11	V. swift	M.
13 46	1	339 + 29	40 + 55	50	V. slow ; streak	M.
14 1	3	28 + 82	147 + 42	53	Slow ; streak	M.
14 45	1	353 + 42	34 + 67	33	„	M.
14 53	1	308 + 15	278 + 39	35	„	M.
15 3	1	140 + 71	142 + 52	19	„	M.
May 4.						
14 34	2	286 + 42	205 + 50	55	Swift ; streak	Be.
14 47	5	316 + 29	306 + 42	16	V. swift	Be.
May 5.						
14 20	3	16 + 63	120 + 66	40	Slow	S.
14 21	3	12 + 60	110 + 70	38	Swift ; streak	D.
14 22	5	50 + 72	111 + 69	21	V. swift	G.
14 35	1	336 + 29	26 + 63	46	V. swift ; streak	G.
14 56	2–3	330 + 60	155 + 69	52	Slow ; streak	G.
14 19	4	309 + 45	192 + 57	65	Swift ; streak	M.
14 35	4	205 + 50	186 + 34	21	„	M.
14 50	♃	309 + 45	192 + 57	65	„	M.
14 54	2	230 + 60	182 + 42	34	„	M.
15 5	2	14 + 88	165 + 45	48	„	M.
15 5	2	257 + 66	187 + 42	44	„	M.
May 6.						
14 20	1	353 + 43	27 + 70	32	Slow ; streak	M.
14 23	2	336 + 47	28 + 81	38	„	M.
May 8.						
14 30	1	309 + 45	199 + 56	64	„	M.

The observers were: M., Maggi, Volpeglino; I., Jadanza, Napoli; Z., Zona, Padova; V., Volante, Aosta; Gi., Garibaldi, Genova; Ba., Battezzati, Alessandria; Bz., Barizzone, Alessandria; Ga., Gai, Alessandria; C., Crabbio, Alessandria; Be., Bellucci, Perugia; S., Sosso, Moncalieri; D., Denza, Moncalieri; G., Giovanola, Moncalieri.

Bristol: 1882, *Dec.* 18.

Observations of Phenomena of Jupiter's Satellites, made at the University Observatory, Durham, in the Year 1882. By G. A. Goldney.

(*Communicated by the Rev. Professor Farrar, D.D.*)

Day of Observation.		Satellite.	Phenomenon.		Power.	G.M. Solar Time of Observation.	G.M. Solar Time of N.A.
						h m s	
Jan.	7	III.	Tr. Ingr.	First contact	195	6 29 37	6 32
				Bisection	,,	6 32 47	
				Last contact	,,	6 38 12	
	7	I.	Tr. Egr.	First contact	,,	10 37 2	10 40
				Bisection	,,	10 39 2	
				Last contact	,,	10 40 32	
	7	II.	Ecl. R.	First seen	,,	12 24 20·3	12 24 30
	17	I.	Ecl. R.	First seen	,,	5 27 36·8	5 27 36
				Full brightness	,,	5 29 25·3	
	22	I.	Occ. D.	First contact	,,	9 24 5	9 26
				Bisection	,,	9 25 35	
				Last seen	,,	9 26 40	
	22	I.	Ecl. R.	First seen	,,	12 54 45·3	12 54 30
				Full brightness	,,	12 57 9·3	
	23	I.	Tr. Ingr.	First contact	,,	6 38 12	6 39
				Bisection	,,	6 39 49	
				Last contact	,,	6 42 16	
	23	II.	Tr. Ingr.	First contact	,,	7 9 3	7 16
				Bisection	,,	7 11 13	
				Last contact	,,	7 14 38	
	23	I.	Tr. Egr.	Bisection	135	8 51 38	8 51
				Last contact	,,	8 53 48	
	23	II.	Tr. Egr.	Bisection	,,	9 50 13	9 54
				Last contact	,,	9 52 58	
	24	I.	Ecl. R.	First seen	195	7 23 38·2	7 23 33
				Full brightness	,,	7 25 30·2	
Feb.	1	III.	Occ. D.	First contact	,,	7 32 2	7 45
				Bisection	,,	7 36 32	
				Last seen	,,	7 41 2	
		II.	Occ. D.	First contact	500	6 49 1	6 52
				Bisection	,,	6 51 31	
				Last seen	,,	6 54 21	
	8	I.	Tr. Egr.	First contact	,,	7 6 1	7 8
				Bisection	,,	7 7 26	
				Last contact	,,	7 9 11	

Day of Observation.	Satellite.	Phenomenon.		Power.	G.M. Solar Time of Observation. h m s	G.M. Solar Time of N.A.
Feb. 15	I.	Tr. Ingr.	First contact	195	6 50 36	6 52
			Bisection	„	6 53 6	
			Last contact	„	6 56 36	
15	I.	Tr. Egr.	Bisection	„	9 4 41	9 5
			Last contact	„	9 6 26	
15	II.	Occ. D.	First contact	„	9 23 1	9 29
			Bisection	„	9 25 11	
			Last seen	„	9 27 36	
16	I.	Ecl. R.	First seen	„	7 40 19·8	7 40 20
			Full brightness	„	7 41 30·8	
19 (*a*)	III.	Tr. Egr.	Bisection	270	8 5 35	8 8
			Last contact	„	8 8 15	
Mar. 3 (*b*)	II.	Tr. Ingr.	First contact	„	9 48 6	9 54
			Bisection	„	9 51 6	
			Last contact	„	9 52 41	
5 (*c*)	II.	Ecl. R.	First seen	„	9 13 55·5	9 12 56
16	III.	Occ. D.	First contact	195	8 39 25	8 44
			Bisection	„	8 41 25	
			Last seen	„	8 43 10	
21	II.	Tr. Egr.	Bisection	„	7 26 55	7 29
			Last contact	„	7 29 15	
26 (*d*)	I.	Tr. Egr.	First contact	135	7 57 11	7 59
			Bisection	„	7 59 31	
			Last contact	„	8 2 41	
Nov. 11	I.	Tr. Ingr.	First contact	380	9 35 20	9 37
			Bisection	„	9 36 14	
			Last contact	„	9 37 53	
11	I.	Tr. Egr.	First contact	„	11 45 59	11 52
			Bisection	„	11 48 38	
			Last contact	„	11 50 37	
12 (*e*)	I.	Occ. R.	Last contact	„	8 59 34	8 59
17	I.	Ecl. D.	First diminution	270	13 17 56·6	13 20 33
			Fading rapidly	„	13 18 42·6	
			Last seen	„	13 20 39·6	
25 (*f*)	I.	Tr. Ingr.	First contact	„	13 4 23	13 7
			Bisection	„	13 6 12	
			Last contact	„	13 8 26	

Day of Observation.	Satellite.	Phenomenon.		Power.	G.M. Solar Time of Observation. h m s	G.M. Solar Time of N.A.
Nov. 27 (*g*)	I.	Tr. Ingr.	First contact	270	7 30 32	7 33
			Bisection	,,	7 32 17	
			Last contact	,,	7 33 42	
27	I.	Tr. Egr.	First contact	,,	9 45 37	9 48
			Bisection	,,	9 47 17	
			Last contact	,,	9 49 2	
28 (*h*)	II.	Occ. R.	Bisection	,,	6 53 53	6 55
			Last contact	,,	6 55 58	
30 (*i*)	II.	Ecl. D.	First diminution	,,	9 48 17·1	9 53 43
			Last seen	,,	9 52 12·1	
Dec. 10	III.	Tr. Ingr.	First contact	,,	7 59 35	8 6
			Bisection	,,	8 4 30	
			Last contact	,,	8 8 59	
10	III.	Sh. Egr.	First contact	,,	9 47 30	9 56
			Bisection	,,	9 50 35	
			Last contact	,,	9 54 15	
10	II.	Tr. Ingr.	First contact	,,	10 31 30	10 42
			Bisection	,,	10 36 45	
			Last contact	,,	10 43 0	
10	I.	Ecl. D.	First diminution	,,	13 29 42·5	13 31 44
			Last seen	,,	13 31 51·5	
11	I.	Tr. Ingr.	First contact	,,	10 57 17	11 0
			Bisection	,,	10 58 54	
			Last contact	,,	11 1 6	
11	I.	Tr. Egr.	First contact	,,	13 10 7	13 15
			Bisection	,,	13 11 57	
			Last contact	,,	13 14 8	
21	I.	Ecl. R.	First seen	,,	6 35 1·7	6 34 51
			Full brightness	,,	6 36 57·7	
23	II.	Tr. Ingr.	First contact	380	11 28 16	11 32
			Bisection	,,	11 30 37	
			Last contact	,,	11 33 30	

Remarks.

(*a*) Very bad definition. (*b*) Images blurred; very bad definition.
(*c*) Rain falling; cloudy after. (*d*) Excessively bad definition.
(*e*) Bad definition. (*f*) Through thin cloud. Images very blurred.
(*g*) Very tremulous. (*h*) Cloudy; images very bad.
(*i*) Thin cloud; hazy.

The observations were all made with the Fräunhofer Equatorial, with an aperture of 6⅜ inches.

Note upon the Longitudes of Madras, Singapore, and Batavia. By Prof. J. A. C. Oudemans.

(*Communicated by J. R. Hind, F.R.S.*)

This summer I have at last received from Mr. Norman Pogson not only the necessary numbers for deducing the difference of longitude of Madras and Singapore, telegraphically determined by us in July 1871, but also the deduction of that longitude itself. My own calculation coincides wholly with his.

By proposing to Mr. Pogson the determination of the above-named difference of longitude, I intended to obtain a telegraphic longitude of Batavia as soon as the longitude of Madras should be telegraphically determined; the difference Batavia-Singapore having been determined already by me and Mr. Soeters half a year before.

I have now prepared a report on that determination, to be presented to the Dutch Colonial Government, and have sent a more detailed abstract of it to the editor of the *Astronomische Nachrichten*, so I will content myself with mentioning here only the result, viz. Singapore (flagstaff on Government Hill), east of Madras (Meridian Circle) $1^h\ 34^m\ 23^s{\cdot}635$, and to add that the personal equation between Mr. Pogson and myself has not been determined, so that it remains in the result.

The longitude of Madras formerly adopted in the *Nautical Almanac* was $5^h\ 20^m\ 57^s{\cdot}3$, but in that of 1882 it appears for the first time as $5^h\ 20^m\ 59^s{\cdot}4$, the "Explanation" printed after the *Almanac* not explaining this change. As this number is less by $0^s{\cdot}25$ than that communicated by General Addison in the *Monthly Notices* of December 1877, I asked Mr. Hind for some information about the origin of the number in the *Nautical Almanac*. He most willingly answered me that the new longitude of Madras was communicated to him by Sir George Airy in a letter of 1878, January 25:—

			h	m	s
Transit of *Venus*.	Mokattam, East of Greenwich	...	2	5	6·320
	Suez, East of Mokattam	...	0	5	6·917
Indian Officers.	Aden, East of Suez	... ...	0	49	42·656
	Bombay, East of Aden	...	1	51	19·983
	Madras, East of Bombay	...	0	29	43·540
	Madras, East of Greenwich	...	5	20	59·416

and added, for further information, the following extract from Sir George Airy's letter:—

"Colonel Walker requests me to transmit to you for insertion (if you see no objection) in the *Nautical Almanac* the following determination of the longitude of Madras by telegraphic operations. The necessary observations were made by Captains W.

M. Campbell and Heaviside, R.E. I do not answer for the accuracy (indeed, I have not all the observations), but I remark that care was taken to determine personal equations and to observe stars on both sides of the zenith; and I have no doubt on the general excellence of the work. The work of the Indian observers was based on that of the Transit of Venus."

Now, the "Account of Observations of the Transit of Venus, 1874, December 8, &c.," edited by Sir George Biddell Airy, 1881, gives the first two of the above-named differences respectively $0^s{\cdot}08$ smaller and $0^s{\cdot}013$ larger. Though I judged for myself that this result being printed and probably of a later date ought to be preferred, I took the liberty to consult Sir George himself, whose answer was affirmative. Thus, taking the differences Mokattam-Greenwich and Suez-Mokattam from the "Account, &c.," we have:—

	h	m	s
Mokattam, East of Greenwich	2	5	6.24
Suez, East of Mokattam	0	5	6.93
Aden, East of Suez	0	49	42.656
Bombay, East of Aden	1	51	19.983
Madras, East of Bombay	0	29	43.540
Singapore, East of Madras	1	34	23.365
Batavia, East of Singapore	0	11	50.985

whence, by addition, east of Greenwich:

	h	m	s
Madras (Meridian Circle)	5	20	59.349
Singapore (flagstaff on Government Hill) ...	6	55	22.714
Batavia (time signal)	7	7	13.70

The new longitude of Batavia exceeds only by $1^s{\cdot}20$ the former one, determined by me in 1858, chiefly by occultations of stars.

At Singapore the Government kindly erected a brick pillar for our observations north of the cathedral; besides its latitude we determined the relative positions of this pillar, the spire of the cathedral, and the flagstaff on Government Hill. The result was:—

	"		s
Pillar, east of flagstaff	21.10	or	1.407
Spire " "	18.48	or	1.232

	°	′	″	
Latitude of flagstaff	1	17	34.4	North.
" spire	1	17	32.8	"
" pillar	1	17	39.8	"

Utrecht: 1882, *Dec.* 27.

The Proper Motions of Telescopic Stars. By Professor Grant.

The work connected with the preparation of the Glasgow Star Catalogue has indicated the existence of several stars below the sixth magnitude having a considerable proper motion. It may be mentioned that the Catalogue contains 6415 stars, of which at least 5000 were taken for re-observation from the first volume of Weisse's Bessel. When the Glasgow results were finally worked out, it became an object of interest to institute a comparison between them and the corresponding results of the Catalogue from which they were originally derived. For this purpose the places in Weisse's Bessel were carefully brought up to 1870, the epoch of the Glasgow Catalogue, and the results in R.A. and N.P.D. of both Catalogues were then confronted together. In this way it was expected that any discordance in either or both of the co-ordinates, depending upon proper motion, would at once reveal itself. Although the agreement between the two Catalogues was on the whole very satisfactory, still a considerable number of discordances did present themselves, and the question now to be considered was whether those discordances were due to proper motion, or whether they were not in many instances attributable to errors of observation and reduction, arising from various sources. For this reason I made it a practice in every case of considerable discordance to search Lalande's *Histoire Céleste*, with the view of ascertaining whether the place of the star under consideration was also contained in that Catalogue. In this search I was generally successful; and if I found that the discordance of Bessel relatively to Glasgow was to the discordance of Lalande relatively to Glasgow, generally speaking, in the proportion of two to three, I concluded that I was really in the track of a proper motion. But to establish this point beyond doubt, it was necessary to ascertain the mean epochs of observation of Lalande and Bessel, an important element which is not contained either in the English edition of Lalande or in Weisse's Bessel. However, a reference to the *Histoire Céleste* and the volumes of the Königsberg Observations supplied me with the desired information. When I had finished the work of comparison, and ascertained beyond doubt the existence of several considerable proper motions in the Glasgow Catalogue, it occurred to me that it would be desirable to know whether the same, or nearly the same, results had been arrived at elsewhere. For this purpose I lately procured from the Library of the Society the seventh volume of the Bonn Observations, containing Argelander's remarkable list of proper motions, which I had not previously seen. Upon examination, I found that Nos. 14, 25, 30, 32, 33, 35, and 37 of the list here given had not escaped the lynx eye of the eminent astronomer of Bonn. I have also ascertained that No. 2 in the list is contained in the Melbourne Catalogue. Probably others in the list

have been already recognised, but I am not acquainted with any such. In a few instances the star is not to be found in Lalande, but an intercomparison of the Glasgow results will be seen to support the adopted P.M. Indeed, in some of the cases of large proper motion, the Glasgow places, ranging as they do over an interval of ten or twelve years, supply of themselves a pretty fair estimation of the proper motion. It will be seen with respect to the double stars 11–12 and 23–24 that the constituent bodies have in each case a common proper motion. They may, therefore, be regarded in both instances as physically connected. I have given in the list which follows: the number of Lalande, the hour and number of Bessel, the number of the Glasgow Catalogue, and the magnitude.

1. *Lalande*, 619; *W. B.* (1) 0,340; *Glasgow*, 123; *Mag.* 6–7.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
Lalande	1793·89	0 21 36·81	1793·89	80 31 3·56
Bessel	1821·83	37·09	1821·83	10·30
Glasgow	1868·45	36·91	1868·45	21·23

The proper motion in R.A. is uncertain, but obviously very small. With respect to the proper motion in N.P.D. we have—

Gl.—B.	... ...	+ 10″·93
Gl.—LL.	... ...	+ 17·67

Applying to the results in N.P.D. a proper motion equal to $+0''\cdot24$, we have—

		Mean N.P.D. 1870.
LL.	... ...	80° 3′ 21″·93
B.	... ...	21·86
Gl.	... ...	21·60

2. *Lalande*, 1198; *W. B.* (1) 0,649; *Glasgow*, 125; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870 h m s	Mean Epoch of Obs.	Mean N.P.D. 1870 ° ′ ″
LL.	1794·90	0 38 25·16	1794·90	88 53 30·63
B.	1821·96	25·55	1821·96	53 52·00
Gl.	1871·91	25·01	1876·66	54 25·20

The P.M. in R.A. is insensible. With respect to the results in N.P.D., we have—

Gl.—B.	... ...	+ 33″·20
Gl.—LL.	... ...	+ 54·57

Applying to the results in N.P.D. a proper motion equal to $+0''\cdot60$, we have—

	Mean N.P.D. 1870.
LL.	88° 54′ 15″·68
B.	20·83
Gl.	21·20

The Glasgow N.P.D. results for the several years of observation are—

Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
1870·94	2	88° 54′ 21″·15	88° 54′ 20″·59
1879·82	1	27·96	22·07
1880·81	2	27·86	21·37

As already stated, the place of this star is given in the Melbourne Catalogue. It is also contained in the Greenwich Catalogue for 1864. Reducing the Greenwich N.P.D. to 1870, and applying in both instances the P.M. above given, we have—

	Mean N.P.D. 1870.
Greenwich	88° 54′ 20″·93
Melbourne	21·68

3. *Lalande*, 3468; *W. B.* (1) I., 819; *Glasgow*, 407; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
LL.	1798·93	1h 46m 31s·51	1798·93	91° 56′ 58″·04
B.	1822·06	31·09	1822·06	57 10·05
Gl.	1872·60	30·54	1875·96	57 28·05

whence

	Mean R.A.	Mean N.P.D.
Gl.—B.	0s·55	+18″·00
Gl.—LL.	0·97	+30·01

Applying a proper motion equal to $-0^s\cdot013$ in R.A., and equal to $+0''\cdot36$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
LL.	1h 46m 30s·59	91° 57′ 23″·62
B.	30·47	27·31
Gl	30·57	25·90

4. *Lalande*, 5353; *W. B.* (1) II., 795; *Glasgow*, 660; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1794·02	2 46 55·99	1794·02	88 33 14·31
B.	1821·96	55·62	1821·96	22·60
Gl.	1869·63	55·47	1879·33	33·64

whence

		Mean R.A. s	Mean N.P.D. ″
Gl.—B.	... ...	−0·15	+11·04
Gl.—LL.	... ...	−0·52	+19·33

Applying a proper motion equal to $-0^s{\cdot}006$ in R.A., and to $+0''{\cdot}20$ in N.P.D., we have—

		Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL....	...	2 46 55·54	88 33 29·51
B. ...	...	55·33	32·21
Gl. ...	...	55·47	31·17

5. *W. B.* (1) II., 927; *Glasgow*, 696; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
B.	1822·86	2 53 36·31	1822·86	84 31 29·10
Gl.	1876·37	38·71	1877·88	36·75

whence

		R.A. s	N.P.D. ″
Gl.—B.	... ...	+2·40	+7·65

Applying a proper motion in R.A. equal to $+0^s{\cdot}075$, and in N.P.D. equal to $+0''{\cdot}14$ we have—

		Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
B. ...	...	2 53 39·84	84 31 35·70
Gl....	...	38·23	35·65

The Glasgow results for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1871·96	1	2 53 38·34	38·19	1871·96	1	84 31 36·28	36·01
1873·09	1	38·51	38·28	1878·84	1	35·47	34·23
9·77		38·91	38·18	1879·86	1	37·14	35·76
		39·07	38·27	1880·86	1	38·09	36·57

The value of P.M. in R.A. indicated by Gl.—B. is $+0^{s}\cdot045$. The value which has been assumed, namely $+0^{s}\cdot075$, appears to agree better with the separate Glasgow observations.

6. *W. B.* (1) III., 173; *Glasgow*, 763; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
B.	1823·05	3 11 12·83	1823·05	75 17 11·00
Gl.	1871·61	12·71	1875·12	25·84

whence

		R.A. s	N.P.D. ″
Gl.—B.	...	=0·12	+14·84

Applying to the N.P.D. results a proper motion equal to $+0''\cdot28$, we have—

			Mean N.P.D. 1870. ° ′ ″
B.	...	...	75 17 24·15
Gl.	...	...	24·41

The Glasgow observations in N.P.D. of this star for the several years are—

Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1870·90	1	75 17 23·11	22·86
1871·01	1	25·52	25·24
1872·91	1	25·24	24·43
1879·88	1	28·24	25·47
1880·89	1	27·09	24·04

The Washington Catalogue also contains this star. Reducing the N.P.D. to 1870, and applying the above proper motion, we have—

Washington N.P.D. = $75^{\circ}\ 17'\ 23''\cdot87$

7. *Lalande*, 10299; *W. B.* (1) V., 512; *Glasgow*, 1341; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·14	5 22 1·18	1797·14	93 33 50·20
B.	1823·02	20 0·92	1823·02	34 8·00
Gl.	1876·89	21 59·53	1877·69	34 56·99

whence

		R.A.	N.P.D.
		s	"
Gl.—B.	...	= −1·39	+48·99
Gl.—LL.	...	= −1·65	+66·79

Applying a proper motion equal to $-0^s{\cdot}021$ in R.A., and to $+0''{\cdot}85$ in N.P.D., we have—

		Mean R.A. 1870.	Mean N.P.D. 1870.
		h m s	° ′ ″
LL.	...	5 22 59·65	93 34 52·13
B.	...	59·93	47·93
Gl.	...	59·67	50·45

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1870·82	1	5 21 59·62	59·64	1872·82	1	93 34 52·33	49·93
1879·80	1	59·51	59·71	1878·94	2	58·33	50·73
1880·04	1	59·45	59·66	1880·04	1	58·98	50·45

8. *W. B.* (1) V., 625; *Glasgow*, 1355; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
B.	1882·01	5 26 20·25	1822·01	86 58 9·30
Gl.	1873·69	20·19	1873·06	57 53·11

whence

		R.A.	N.P.D.
		s	″
Gl.—B.	...	= −0·06	−16·19

Applying to the N.P.D. results a proper motion equal to $-0''{\cdot}31$, we have—

			Mean N.P.D. 1870.
			° ′ ″
B.	...	...	86 57 53·94
Gl.	...	...	54·09

The Glasgow results in N.P.D. for the several years are—

Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		° ′ ″	″
1867·15	1	86 57 54·24	53·33
1873·17	1	52·12	53·13
1878·87	1	52·98	55·82

9. *Lalande*, 11327; *W. B.* (1) V., 1305; *Glasgow*, 1477; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·14	5 51 55·36	1797·14	94 39 15·04
B.	1824·05	55·48	1824·05	18·70
Gl.	1876·96	55·44	1876·46	31·62

whence

	R.A. s	N.P.D. ″
Gl.—B. ...	−0·04	+12·92
Gl.—LL. ...	+0·08	+16·58

Applying to the results in N.P.D. a proper motion equal to $+0''\cdot22$, we have—

	Mean N.P.D. 1870. ° ′ ″
LL.	94 39 31·07
B.	28·81
Gl.	30·20

10. *Lalande*, 17046; *W. B.* (1) VIII., 828; *Glasgow*, 2205; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1796·20	8 32 45·28	1796·20	77 59 32·42
B.	1822·24	44·46	1822·24	77 59 48·00
Gl.	1868·17	44·30	1868·17	78 0 10·44

whence

	R.A. s	N.P.D. ″
Gl.—B. ...	−0·16	+22·44
Gl.—LL. ...	−0·98	+38·02

The proper motion in R.A. is uncertain; a comparison of Glasgow with Bessel gives $-0^s\cdot004$. On the other hand, a comparison of Glasgow with Lalande gives $-0^s\cdot013$. Applying to the results in N.P.D. a proper motion equal to $+0''\cdot50$, we have—

	Mean N.P.D. 1870. ° ′ ″
LL.	78 0 9·34
B.	11·88
Gl.	11·35

11. *Lalande*, 17050; *W. B.* (1) VIII., 834; *Glasgow*, 2206; *Mag.* 8.

12. *Lalande*, 17053; *W. B.* (1) VIII., 835; *Glasgow*, 2207; *Mag.* 9.

These two stars constitute a double star, and an intercomparison of the observations would seem to prove beyond doubt the existence of a physical connection between them. As this is a question of peculiar interest, I have searched out, not without success, other authorities for the places of the stars. I find that the places of both stars are contained in the Greenwich twelve-year Catalogue (Nos. 771–2). Struve has also recorded the relative position of the two stars in the *Mensuræ Micrometricæ* (p. 191); and he has given the absolute position of Lalande 17050 in the *Positiones Mediæ* (No. 1022). Considering first Lalande 17050, we have the following places of the star reduced to 1870:—

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·14	8 32 48·02	1797·14	83 45 45·52
B.	1822·12	48·27	1822·12	54·00
Struve	1823·40	48·14	1823·40	52·30
Greenwich	1845·25	48·28	1845·25	58·87
Glasgow	1868·21	48·50	1874·79	69·33

whence

		R.A. s	N.P.D. ″
Gl.—B.	...	= +0·23	+15·33
Gl.—LL.	...	= +0·48	+23·81

Assuming a proper motion in R.A. equal to $+0^s{\cdot}006$, and in N.P.D. to $+0''{\cdot}30$, we have—

		Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	...	8 32 48·46	83 46 7·38
B.	...	48·56	8·37
Struve	...	48·42	6·28
Greenwich	...	48·43	6·37
Glasgow	...	48·47	7·73

Again, with respect to Lalande 17053, we have—

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·14	8 32 48·72	1797·14	83 45 21·72
B.	1822·12	49·23	1822·12	31·50
Greenwich	1845·25	49·31	1845·25	36·30
Glasgow	1872·43	49·60	1874·75	45·95

Applying a proper motion equal to +0·006 in R.A., and to +0″·30 in N.P.D., we have—

		Mean R.A. 1870 h m s	Mean N.P.D. 1870 ° ′ ″
LL.	...	8 32 49·16	83 45 43·58
B.	...	49·52	45·87
Greenwich	...	49·46	43·72
Glasgow	...	49·57	44·53

It appears, then, that the same proper motion is capable of representing the secular changes in the places of both stars.

13. *W. B.* (1) VIII., 961; *Glasgow*, 2235; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
B.	1824·17	8 37 34·07	1824·17	93 43 46·30
Gl.	1873·37	33·92	1873·11	44 5·47

whence

		R.A. s	N.P.D. ″
Gl.—B.	... ...	−0·15	+19·17

Applying a proper motion equal to −0s·003 in R.A., and to +0″·40 in N.P.D., we have—

		Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
B. ...	...	8 37 33·93	93 44 4·63
Gl. ...	...	33·93	4·23

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1868·13	1	8 37 33·86	33·86	1868·13	1	93 44 3·56	4·31
1873·12	1	33·98	33·99	1873·12	1	6·14	4·89
1874·13	1	34·03	34·04	1878·09	1	6·70	3·46
1878·09	1	33·82	33·84				

14. *Lalande*, 20100; *W. B.* (1) X., 240; *Glasgow*, 2693; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1796·20	10 15 14·57	1796·20	78 1 1·25
B.	1822·32	14·61	1822·32	6·20
Gl.	1873·49	14·43	1877·11	29·21

whence

			R.A.	N.P.D.
			s	"
Gl.—B.	...	...	−0·18	+23·01
Gl.—LL.	...	...	−0·14	+27·96

Applying a proper motion equal to −0s·003 in R.A., and to +0″·40 in N.P.D., we have—

			Mean R.A. 1870.	Mean N.P.D. 1870.
			h m s	° ′ ″
LL.	...	...	10 15 14·35	78 1 30·77
B.	...	...	14·44	25·27
Gl.	...	...	14·44	26 37

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1867·20	1	10 15 14·36	14·35	1873·12	1	78 1 27·97	26·72
1873·12	1	14·49	14·50	1878·29	1	29·00	25·68
1880·15	1	14·45	14·48	1879·91	1	30·67	26·71

15. *Lalande*, 20155; *W. B.* (1) X., 272; *Glasgow*, 2702; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1798·19	10 17 1·70	1798·19	86 42 34·42
B.	1823·27	1·54	1823·27	42.20
Gl.	1870·16	1·17	1874·38	55·03

whence

			R.A.	N.P.D.
			s	"
Gl.—B.	...	...	−0·37	+12·83
Gl.—LL.	...	...	−0·53	+20·61

Applying a proper motion equal to −0s·007 in R.A., and to +0″·26 in N.P.D., we have—

			Mean R.A. 1870.	Mean N.P.D. 1870.
			h m s	° ′ ″
LL.	...	...	10 17 1·20	86 42 53·09
B.	...	...	1·21	54·35
Gl.	...	...	1·17	53·89

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1867·16	1	10 17 1·12	1·10	1867·16	1	86 42 54·12	53·38
1873·16	1	1·22	1·24	1873·16	1	53·31	54·13
				1878·59	2	56·34	54·11

16. *Lalande*, 20679; *W. B.* (1) X., 633; *Glasgow*, 2783; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1795·25	10 36 10·98	1795·25	91 29 28·81
B.	1822·28	11·09	1822·28	37·40
Gl.	1875·79	11·02	1872·02	48·47

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	−0·07	+11·07
Gl.—LL.	+0·04	+19·66

Applying a proper motion equal to $+0''\cdot24$ in N.P.D., we have—

	Mean N.P.D. 1870.
	° ′ ″
LL.	91 29 46·75
B.	48·85
Gl.	47·99

The Glasgow N.P.D. results for the several years are—

Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		° ′ ″	″
1869·24	2	91 29 48·52	48·70
1871·32	1	47·78	47·46
1878·26	1	49·07	47·09

17. *Lalande*, 20882; *W. B.* (1) X., 782; Glasgow, 2809; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1796·26	10 44 25·60	1796·26	80 4 28·81
B.	1822·24	25·57	1822·24	36·00
Gl.	1880·20	25·46	1877·62	49·69

whence

	R.A.	N.P.D.
	s	″
Gl.—B. ...	−0·11	+13·69
Gl.—LL. ...	−0·14	+20·88

Applying a proper motion equal to $-0^s\cdot001$ in R.A., and to $+0''\cdot25$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
LL. ...	10 44 25·53	80 4 47·14
B. ...	25·52	47·94
Gl. ...	25·46	47·79

The Glasgow N.P.D. results for the several years are—

Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		° ′ ″	″
1870·22	1	80 4 47·94	47·89
1879·91	1	49·91	47·43
1880·18	2	50·46	47·92

18. *Lalande*, 21586; *W. B.* (1) XI., 193; *Glasgow*, 2920; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1796·27	11 12 47·09	1796·27	90 56 7·43
B.	1823·27	46·74	1823·27	14·30
Gl.	1874·68	45·68	1876·95	20·66

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	−1·06	+6·36
Gl.—LL.	−1·41	+13·23

Applying a proper motion equal to $-0^s{\cdot}020$ in R.A., and to $+0''{\cdot}14$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
LL. ...	11 12 45·52	90 56 17·75
B. ...	45·81	20·84
Gl. ...	45·77	19·69

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870	Corrected for P.M.
		h m s	s			° ′ ″	″
1872·35	3	11 12 45·78	45·83	1872·32	1	90 56 19·26	18·94
1875·18	2	45·63	45·73	1878·23	1	21·24	20·09
1877·14	1	45·66	45·80	1880·29	1	21·47	20·03
1878·23	1	45·53	45·69				

19. *Lalande*, 22385; *W. B.* (1) XI., 774; *Glasgow*, 3049; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1796·26	11 45 44·53	1796·26	79 20 4·89
B.	1822·23	43·83	1822·23	20 3·00
Gl.	1877·25	42·72	1877·47	19 58·48

whence

		R.A.	N.P.D.
		s	″
Gl.—B.	... ...	−1·11	−4·52
Gl.—LL.	... ...	−1·81	−6·41

Applying a proper motion equal to $-0^s{\cdot}020$ in R.A., and to $-0''{\cdot}08$ in N.P.D., we have—

		Mean R.A. 1870.	Mean N.P.D. 1870.
		h m s	° ′ ″
LL.	...	11 45 43·06	79 20 58·99
B.	...	42·88	59·18
Gl.	...	42·87	59·08

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1873·12	1	11 45 42·74	42·80	1873·12	1	79 19 57·16	57·41
1876·28	1	42·73	42·85	1878·26	2	59·00	59·66
1878·27	1	42·91	43·07	1880·22	1	58·77	59·59
1879·29	2	42·61	42·79				

20. *Lalande*, 22901 ; *W. B.* (1) XII., 75 ; *Glasgow*, 3122 ; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1796·26	12 6 16·28	1796·26	79 13 2·91
B.	1824·25	17·25	1824·25	18·70
Gl.	1877·59	17·71	1878·32	37·69

whence

		R.A.	N.P.D.
		s	″
Gl.—B.	... ...	= +0·46	+18·99
Gl.—LL.	... ...	= +1·43	+34·78

Applying a proper motion equal to $+0^s{\cdot}006$ in R.A., and to $+0''{\cdot}38$ in N.P.D., we have—

		Mean R.A. 1870.	Mean N.P.D. 1870.
		h m s	° ′ ″
LL.	... ...	12 6 16·94	79 13 30·93
B.	... ...	17·66	36·08
Gl.	... ...	17·64	34·53

21. *Lalande*, 22908; *W. B.* (1) XII., 77; *Glasgow*, 3123; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1798·27	12 6 34·85	1798·27	78 25 22·64
B.	1823·24	34·56	1823·24	25 34·50
Gl.	1874·48	35·07	1875 91	26 6·33

whence

	R.A. s	N.P.D. ″
Gl.—B.	= +0·51	+31·83
Gl.—LL.	= +0·22	+43·69

Applying a proper motion equal to $+0^s{\cdot}010$ in R.A., and to $+0''{\cdot}58$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	12 6 35·57	78 26 4·24
B.	35·02	1·62
Gl.	35·03	2·90

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1867·29	1	12 6 34·94	34·97	1867·29	1	78 26 1·69	2·26
1870·26	1	34·98	34·98	1870·25	1	2·23	2·09
1873·16	1	35·11	35·08	1880·33	2	9·54	3·55
1880·32	1	35·03	34·93	1881·37	1	8·64	2·05
1881·35	1	35·27	35·16				

22. *Lalande*, 22914; *W. B.* (1) XII., 80; *Glasgow*, 3126; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1796·26	12 6 51·22	1796·26	79 13 5·84
B.	1824·25	51·26	1824·25	19·05
Gl.	1873·77	51·45	1879·30	34·61

whence

	R.A. s	N.P.D. ″
Gl.—B.	= +0·19	+15·56
Gl.—LL.	= +0·23	+28·77

Applying a proper motion equal to $+0^s.003$ in R.A., and to $+0''.31$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	12 6 51·44	79 13 28·70
B.	51·40	33·23
Gl.	51·44	31·73

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1869·30	1	12 6 51·45	51·45	1878·26	2	79 13 34·21	31·65
1878·23	1	51·45	51·43	1880·30	2	35·01	31·81

23. *W. B.* (1) XIII., 257; *Glasgow*, 3367; *Mag.* 8.

24. *W. B.* (1) XIII., 259; *Glasgow*, 3368; *Mag.* 8.

These two stars constitute a double star, and as they appear to have a common proper motion, we may presume that there exists between them a physical connection. Their relative position is given in Struve's *Mensuræ Micrometricæ* (p. 192), and the absolute position of the former is contained in the *Pos. Med.* (No. 1517). Taking the case of the first star, we have—

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
B.	1822·36	13 17 2·90	1822·36	86 36 25·45
Gl.	1874·91	2·78	1873·99	13·16

whence

	R.A. s	N.P.D. ″
Gl.—B.	−0·12	−12·29

Applying a proper motion equal in R.A. to $-0^s.002$, and in N.P.D. to $+0''.24$, we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
B.	13 17 2·81	86 36 14·02
Gl.	2·79	14·12

The mean epoch of Struve's observation of the star is 1823·70, and the position similarly reduced to 1870 is—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
Struve	13 17 2·63	86 36 13·87

With respect to the second star we have—

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
B.	1822·36	13 17 4·34	1822·36	86 36 18·80
Gl.	1879·73	4·51	1878·37	6·12

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	+0·17	−12·68

Applying the proper motion found for the first star we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
B.	13 17 4·25	86 36 5·36
Gl.	4·53	4·11

25. *Lalande*, 25404; *W. B.* (1) XIII., 679; *Glasgow*, 3438; *Mag.* 6.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
Ll.	1797·28	13 40 33·43	1797·28	82 59 32·74
B.	1823·31	32·34	1823·31	35·10
G.	1872·27	30·94	1873·62	41·35

whence

	R.A.	N.P.D.
	s.	″
Gl.—B.	−1·40	+6·25
Gl.—Ll.	−2·49	+8·61

Applying a proper motion equal to $-0^s{\cdot}030$ in R.A., and to $+0''{\cdot}10$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
Ll.	13 40 31·25	82 59 41·47
B.	30·90	40·70
Gl.	30·87	40·92

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1871·28	2	13 40 30·87	30·90	1871·28	2	82 59 41·44	41·31
1874·26	1	31·09	31·22	1878·31	1	41·18	40·35

26. *Lalande*, 26042; *W. B.* (1) XIV., 74; *Glasgow*, 3524; *Mag.* 8–9.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1795·35	14 6 3·13	1795·35	92 41 23·54
B.	1822·34	2·84	1822·34	36·50
Gl.	1878·77	2·04	1880·12	52·92

whence

	R.A. s	N.P.D. ″
Gl.—B. ...	−0·80	+16·42
Gl.—LL. ...	−1·09	+29·38

Applying a proper motion equal to $-0^s{\cdot}015$ in R.A., and to $+0''{\cdot}32$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	14 6 2·01	92 41 47·43
B.	2·13	51·75
Gl.	2·17	49·68

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1872·39	1	14 6 2·25	2·28	1878·24	2	92 41 51·17	48·53
1880·23	1	2·03	2·18	1880·28	2	54·13	50·84
1881·23	2	1·94	2·11	1881·26	3	53·29	49·69

27. *Lalande*, 26289; *W. B.* (1) XIV., 281; *Glasgow*, 3562; *Mag.* 6.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·39	14 16 35·44	1797·39	88 8 16·75
B.	1822·39	36·30	1822·39	32·00
Gl.	1872·33	36·53	1878·08	57·49

whence

	R.A. s	N.P.D. ″
Gl.—B.	+0·23	+25·49
Gl.—LL.	+1·09	+40·74

Applying a proper motion equal to $+0^s{\cdot}005$ in R.A., and to $+0''{\cdot}48$ in N.P.D., we have—

	Mean R.A. 1870	Mean N.P.D. 1870
	h m s	° ′ ″
LL.	14 16 35·80	88 8 51·60
B.	36·54	54·85
Gl.	36·52	53·61

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1871·35	1	14 16 36·50	36·50	1873·30	1	88 8 56·13	54·55
1873·30	1	36·56	36·54	1878·38	1	56·98	52·96
				1880·32	2	58·43	53·48

28. *Lalande*, 27331; *W. B.* (1) XIV., 1005; *Glasgow*, 3703; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1799·40	14 54 15·64	1799·40	80 51 51·42
B.	1823·37	15·82	1823·37	51 59·00
Gl.	1874·32	15·37	1877·15	52 18·46

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	−0·45	+19·46
Gl.—LL.	−0·27	+27·04

Applying a proper motion equal to $-0^s{\cdot}010$ in R.A., and to $+0''{\cdot}36$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
LL.	14 54 14·93	80 51 16·84
B.	15·36	15·79
Gl.	15·33	15·89

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1868·41	1	14 54 15·34	15·32	1868·41	1	80 52 15·19	15·76
1874·33	3	15·40	15·44	1878·39	2	18·86	15·84
1880·21	1	15·31	15·41	1880·28	2	19 69	15·99

N 2

26. *Lalande*, 26042; *W. B.* (1) XIV., 74; *Glasgow*, 3524; *Mag.* 8–9.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1795·35	14 6 3·13	1795·35	92 41 23·54
B.	1822·34	2·84	1822·34	36·50
Gl.	1878·77	2·04	1880·12	52·92

whence

	R.A. s	N.P.D. ″
Gl.—B. ...	−0·80	+16·42
Gl.—LL. ...	−1·09	+29·38

Applying a proper motion equal to $-0^s \cdot 015$ in R.A., and to $+0'' \cdot 32$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	14 6 2·01	92 41 47·43
B.	2·13	51·75
Gl.	2·17	49·68

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1872·39	1	14 6 2·25	2·28	1878·24	2	92 41 51·17	48·53
1880·23	1	2·03	2·18	1880·28	2	54·13	50·84
1881·23	2	1·94	2·11	1881·26	3	53·29	49·69

27. *Lalande*, 26289; *W. B.* (1) XIV., 281; *Glasgow*, 3562; *Mag.* 6.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·39	14 16 35·44	1797·39	88 8 16·75
B.	1822·39	36·30	1822·39	32·00
Gl.	1872·33	36·53	1878·08	57·49

whence

	R.A. s	N.P.D. ″
Gl.—B.	+0·23	+25·49
Gl.—LL.	+1·09	+40·74

Applying a proper motion equal to $+0^s{\cdot}005$ in R.A., and to $+0''{\cdot}48$ in N.P.D., we have—

	Mean R.A. 1870	Mean N.P.D. 1870
	h m s	° ′ ″
LL.	14 16 35·80	88 8 51·60
B.	36·54	54·85
Gl.	36·52	53·61

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1871·35	1	14 16 36·50	36·50	1873·30	1	88 8 56·13	54·55
1873·30	1	36·56	36·54	1878·38	1	56·98	52·96
				1880·32	2	58·43	53·48

28. *Lalande*, 27331; *W. B.* (1) XIV., 1005; *Glasgow*, 3703; *Mag.* 7–8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1799·40	14 54 15·64	1799·40	80 51 51·42
B.	1823·37	15·82	1823·37	51 59·00
Gl.	1874·32	15·37	1877·15	52 18·46

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	−0·45	+19·46
Gl.—LL.	−0·27	+27·04

Applying a proper motion equal to $-0^s{\cdot}010$ in R.A., and to $+0''{\cdot}36$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
LL.	14 54 14·93	80 51 16·84
B.	15·36	15·79
Gl.	15·33	15·89

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1868·41	1	14 54 15·34	15·32	1868·41	1	80 52 15·19	15·76
1874·33	3	15·40	15·44	1878·39	2	18·86	15·84
1880·21	1	15·31	15·41	1880·28	2	19 69	15·99

N 2

29. *Lalande*, 27468; *W. B.* (1) XIV., 1090; *Glasgow*, 3717; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1797·36	14 58 48·12	1797·36	83 11 16·54
B.	1823·41	48·18	1823·41	25·10
Gl.	1878·35	48·03	1876·06	40·01

whence

	R.A. s	N.P.D. ″
Gl.—B.	−0·15	+14·91
Gl.—LL.	−0·10	+23·47

Applying a proper motion equal to $-0^s{\cdot}002$ in R.A., and $+0''{\cdot}32$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	14 58 47·98	83 11 39·06
B.	48·09	39·54
Gl.	48·05	38·13

30. *Lalande*, 27744; *W. B.* (1) XV., 99; *Glasgow*, 3752; *Mag.* 6–7.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1798·32	15 7 25·84	1798·32	90 50 5·81
B.	1822·44	23·86	1822·44	25·30
Gl.	1878·10	19·16	1878·30	49·67

whence

	R.A. s	N.P.D. ″
Gl.—B.	−4·70	+24·37
Gl.—LL.	−6·68	+43·86

Applying a proper motion equal to $-0^s{\cdot}085$ in R.A., and to $+0''{\cdot}55$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	15 7 19·75	90 50 45·23
B.	19·82	51·35
Gl.	19·85	45·11

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s				° ′ ″	″
1871·38	2	15 7 19·81	19·93	1871·38	2	90 50 45·81	45·05
1878·26	1	18·98	19·68	1878·26	1	48·81	45·27
1879·29	3	19·08	19·87	1880·21	1	51·36	45·75
1881·35	3	18·85	19·81	1881·29	4	51·40	45·19

31. *W. B.* (1) XV., 583; *Glasgow*, 3845; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
B.	1823·40	15 31 43·94	1823·40	79 18 49·50
Gl.	1876·09	44·42	1876·93	19 12·70

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	+0·48	+23·20

Applying a proper motion equal to $+0^s{\cdot}010$ in R.A., and to $+0''{\cdot}43$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
B.	15 31 44·41	79 18 9·45
Gl.	44·36	9·72

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1868·46	1	15 31 44·34	44·35	1868·46	1	79 19 8·45	9·11
1872·38	1	44·28	44·26	1872·38	1	10·62	9·60
1873·38	1	44·39	44·36	1873·38	1	9·59	8·14
1874·35	1	44·31	44·27	1880·21	1	14·88	10·49
1881·35	3	44·54	44·43	1881·35	3	15·13	10·25

32. *Lalande*, 29437; *W. B.* (1) XVI., 14; *Glasgow*, 3978; *Mag.* 6.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1797·36	16 2 46·05	1797·36	83 14 2·06
B.	1823·41	46·60	1823·41	23·80
Gl.	1876·22	47·41	1877·20	63·41

whence

	R.A.	N.P.D.
	s	"
Gl.—B.	= +0·81	+39·61
Gl.—LL.	= +1·36	61·35

Applying a proper motion equal to $0^s·016$ in R.A., and to $+0''·72$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
LL.	16 2 47·21	83 14 54·36
B.	47·34	57·35
Gl.	47·31	58·23

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1867·42	1	16 2 47·28	47·32	1867·42	1	83 14 55·71	57·57
1871·39	1	47·37	47·35	1871·39	1	58·67	57·67
1877·44	1	47·40	47·28	1878·39	1	64·68	58·64
1878·39	1	47·48	47·35	1880·30	2	65·67	58·25
1881·35	2	47·46	47·28	1881·30	2	66·73	58·59

33. *Lalande*, 30044; *W. B.* (1) XVI., 439; *Glasgow*, 4066; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1794·48	16 24 7·11	1794·48	85 27 22·86
B.	1822·45	6·52	1822·45	28 6·60
Gl.	1874·39	4·71	1876·07	29 20·66

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	−1·81	+74·06
Gl.—LL.	−2·40	117·80

Applying a proper motion equal in R.A. to $-0^s·030$, and in N.P.D. to $1''·42$, we have—

	R.A. 1870.	N.P.D. 1870.
	h m s	° ′ ″
LL. ...	16 24 4·70	85 29 10·10
B. ...	5·00	13·06
Gl. ...	4·85	12·04

The Glasgow results for the several years of observation are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1868·46	1	16 24 4·74	4·79	1868·46	1	85 29 8·60	10·79
1869·44	1	4·94	4·76	1869·44	1	10·48	11·17
1871·35	1	4·75	4·79	1871·35	1	13·57	11·65
1881·34	2	4·56	4·92	1880·29	2	26·94	12·33
				1881·34	2	29·05	12·95

34. *Lalande*, 30338; *W. B.* (1) XVI., 644; *Glasgow*, 4112; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1798·44	16 34 21·71	1798·44	92 34 36·97
B.	1823·06	21·29	1823·06	52·80
Gl.	1871·89	21·16	1874·09	75·43

whence

	R.A. s	N.P.D. ″
Gl.—B.	= −0·13	+22·63
Gl.—LL.	= −0·55	+38·46

Applying a proper motion equal to $0^s{\cdot}005$ in R.A., and to $+0''{\cdot}47$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	16 34 21·36	92 35 10·60
B.	21·05	14·86
Gl.	21·16	13·51

35. *Lalande*, 30694; *W. B.* (1) XVI., 873; *Glasgow*, 4162; *Mag.* 6–7.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1798·32	16 46 29·41	1798·32	89 43 29·85
B.	1822·44	27·84	1822·44	44 2·00
Gl.	1878·60	25·43	1878·42	45 29·11

whence

	R.A. s	N.P.D. ′ ″
Gl.—B.	= −2·41	+1 27·11
Gl.—LL.	= −3·98	+1 59·26

Applying a proper motion equal to $-0^s{\cdot}045$ in R.A., and to $+1''{\cdot}47$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
LL.	16 46 26·33	89 45 15·22
B.	25·80	11·91
Gl.	25·80	16·73

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1867·46	1	16 46 25·90	25·81	1867·46	1	89 45 11·39	15·10
1872·41	1	25·49	25·59	1872·41	1	20·20	16·66
1876·54	2	25·51	25·79	1878·31	1	29·96	17·75
1878·31	1	25·40	25·77	1880·26	3	31·49	16·41
1880·26	3	25·34	25·78	1881·32	4	33·76	17·12
1881·32	3	25·30	25·79				

36. *Lalande*, 31065; *W. B.* (1) XVI., 1089; *Glasgow*, 4203; *Mag.* 6.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
LL.	1779·39	16 58 39·54	1797·39	89 5 48·38
B.	1822·44	39·84	1822·44	54·00
Gl.	1869·13	39·79	1869·13	75·14

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	$= -0{\cdot}05$	$+21{\cdot}14$
Gl.—LL.	$= +0{\cdot}25$	$+26{\cdot}76$

The proper motion in R.A. is insensible. Applying a proper motion equal to $+0''{\cdot}41$ in N.P.D., we have—

	Mean N.P.D. 1870.
	° ′ ″
LL.	89 6 18·15
B.	13·50
Gl.	15·50

37. *W. B.* (1) XVII., 322; *Glasgow*, 4294; *Mag.* 7.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
B.	1822·50	17 19 19·38	1822·50	87 42 43·50
Gl.	1879·54	16·94	1879·36	43 52·82

whence

	R.A.	N.P.D.
	s	′ ″
Gl.—B.	= −2·44	+1 9·32

Applying a proper motion equal to $-0^s{\cdot}043$ in R.A., and to $+1''{\cdot}22$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N.P.D. 1870.
	h m s	° ′ ″
B.	17 19 17·34	87 43 41·45
Gl.	17·35	41·40

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s	s			° ′ ″	″
1871·43	1	17 19 17·23	17·29	1871·43	1	87 43 44·15	42·41
1880·25	4	16·93	17·38	1878·48	2	51·27	40·93
1881·30	3	16·85	17·33	1880·25	4	53·71	41·20
				1881·40	3	55·55	41·65

38. *W. B.* (1) XVII., 514; *Glasgow*, 4330; *Mag.* 8–9.

	Mean Epoch of Obs.	Mean R.A. 1870.	Mean Epoch of Obs.	Mean N.P.D. 1870.
		h m s		° ′ ″
B.	1822·48	17 28 27·19	1822·48	83 54 53·55
Gl.	1878·96	25·51	1877·37	32·87

whence

	R.A.	N.P.D.
	s	″
Gl.—B.	= −1·68	−20·68

Applying a proper motion equal to $-0^s{\cdot}029$ in R.A., and to $-0''{\cdot}40$ in N.P.D., we have—

	Mean R.A. 1870.	Mean N P.D. 1870.
	h m s	° ′ ″
B.	17 28 25·67	83 54 35·49
Gl.	25·78	35·82

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870.	Corrected for P.M.	Year.	No. of Obs.	Mean N.P.D. 1870.	Corrected for P.M.
		h m s				° ′ ″	″
1871·41	1	17 28 25·76	25·80	1871·41	1	83 54 35·15	35·71
1880·34	2	25·45	25·76	1880·35	2	31·73	35·87
1881·35	2	25·44	25·78				

Applying a proper motion equal to $-0^s{\cdot}003$ in R.A., and to $-0''{\cdot}61$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
B.	22 58 53·76	80 15 13·90
Gl.	53·77	13·74

The Glasgow places for the several years are—

Year.	No. of Obs.	Mean R.A. 1870. h m s	Corrected for P.M. s	Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1872·63	1	22 58 53·77	53·78	1872·63	1	80 15 11·13	12·73
1876·71	1	53·91	53·93	1877·91	1	9·32	14·14
1877·85	1	53·71	53·73	1878·80	1	7·95	13·32
1878·80	1	53·66	53·69	1880·64	1	8·27	14·76

43. *Lalande*, 46572–3; *W. B.* (1) XXIII., 789; *Glasgow* 6297; *Mag.* 8.

	Mean Epoch of Obs.	Mean R.A. 1870. h m s	Mean Epoch of Obs.	Mean N.P.D. 1870. ° ′ ″
LL.	1795·76	23 39 41·76	1795·76	80 55 33·89
B.	1822·86	41·67	1822·86	38·70
Gl.	1870·94	41·48	1873·55	50·23

whence

	R.A. s	N.P.D. ″
Gl.—B.	−0·19	+11·53
Gl.—LL.	−0·28	+16·34

Applying a proper motion equal to $-0^s{\cdot}004$ in R.A., and to $+0''{\cdot}22$ in N.P.D., we have—

	Mean R.A. 1870. h m s	Mean N.P.D. 1870. ° ′ ″
LL.	23 39 41·46	80 55 50·22
B.	41·48	49·07
Gl.	41·48	49·45

The Glasgow N.P.D. results for the several years are—

Year.	No. of Obs.	Mean N.P.D. 1870. ° ′ ″	Corrected for P.M. ″
1870·94	2	80 55 49·77	49·56
1878·78	1	51·14	49·21

Erratum.

Vol. xliii. p. 19, Apparent Declination of Great Comet on Sept. 17, *for* 1° 37′ 25″·3 *read* 1° 27′ 25″·3.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. FEBRUARY 9, 1883. No. 4.

E. J. STONE, M.A., F.R.S., President, in the Chair.

A. William Dauglish, 34 Queen Anne Street, W.;
George W. H. Maclear, Royal Observatory, Cape of Good Hope; and
The Rev. Edward F. Shaw, 122 Elgin Road, Maida Vale, W.;

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-THIRD ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resident	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1881 ...	222	364	3	5	594	43	1	638
Since elected	+4	+22	...	...	...	+5	...	...
Deceased	−2	−10	−1	...	...	−2	...	...
Removals	+6	−6	...	...	...	...	...	...
Resigned	...	−7	...	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...	...
December 31, 1882 ...	230	361	2	5	598	46	1	645

Mr. Barrow's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers, Jan. 1, 1882:						
Credited in pass book	601	5	1			
Cheque not credited	2	2	0			
Balance in hand of Assistant Secretary on account of Turnor Fund	13	2	9			
„ on Petty Cash account	10	3	2			
				626	13	0
Dividend on £7,500 Consols	110	3	2			
„ £5,700 New 3 per cent. Stock ...	83	14	5			
„ £7,500 Consols	110	3	2			
„ £5,700 New 3 per cent. Stock ...	83	3	9			
Interest on money on deposit at Bankers' ...	11	5	10			
				398	10	4
Received on account of Subscriptions:						
Arrears	161	14	0			
261 Contributions for 1882	548	2	0			
1 Contribution for 1883	2	2	0			
24 Admission Fees	50	8	0			
19 First Contributions	30	9	0			
				792	15	0
10 Composition Fees				210	0	0
Sales of Publications:						
At Society's Rooms, 1882	45	8	1			
At Williams & Norgate's, 1881	48	10	4			
				93	18	5
Due to Assistant Secretary on Petty Cash account, Dec. 31, 1882				2	13	7
				£2,124	10	4

Astronomical Society, from Dec. 31, 1881, to Dec. 31, 1882.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary Salary	225	0	0			
" " for assistance in editing Society's publications...	50	0	0			
				275	0	0
Income Tax and House Duty				9	3	9
Fire Insurance				7	16	6
Printing: Spottiswoode & Co.	490	9	0			
" H. Richardson...	0	12	6			
				491	1	6
Computation of Ephemerides in *Monthly Notices*				12	10	0
Lithography and Engraving				19	5	10
Turnor Fund: Purchase of Books for Library ...				16	7	5
Binding Books in Library				26	17	6
House Expenses	37	19	2			
Wages	18	4	0			
Stamps and postage	54	4	2			
Carriage of books and parcels	3	19	9			
Stationery and office expenses	11	19	7			
Expenses of meetings	20	0	0			
Coals and gas	52	6	1			
Fittings, repairs, &c.	5	7	11			
Sundries	3	17	4			
				207	18	0
Mrs. Jackson-Gwilt's annuity				8	19	0
Deduction on Cheque				0	0	3
Balance at Bankers', credited in pass book, Dec. 30, 1882	514	4	9			
Amounts not credited till Jan. 1883	16	0	6			
On deposit account at Bankers	500	0	0			
				1,030	5	3
Balance in hand of Assistant Secretary on account of Turnor Fund	6	15	4			
Balance in hand of Hon. Secretary on account of payment for computation of Ephemerides...	12	10	0			
				19	5	4
				£2,124	10	4

Examined and found to be correct, Jan. 9, 1883.

F. C. Penrose,

Robt. J. Lecky.

Assets and present property of the Society, January 1, 1883:—

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 30, 1882, as credited in pass book	514	4	9			
Amounts not credited till Jan. 1883	16	0	6			
On deposit account at Bankers'	500	0	0			
Balance in hand of Assistant Secretary on account of Turnor Fund	6	15	4			
Balance in hand of Hon. Secretary on account of payment for computation of Ephemerides ...	12	10	0			
	1,049	10	7			
Less due to Assistant Secretary on Petty Cash account	2	13	7			
				1,046	17	0
Due on account of subscriptions:						
2 Contributions of 5 years' standing ...	21	0	0			
1 „ 4 „ ...	8	8	0			
13 „ 3 „ ...	81	18	0			
31 „ 2 „ ...	130	4	0			
62 „ 1 „ ...	130	4	0			
2 Admission fees and first contributions ...	7	7	0			
	379	1	0			
Less Contribution paid in advance ...	2	2	0			
				376	19	0
Due for Publications from Messrs. Williams & Norgate (for sales during 1882)				48	7	3

£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

£5,700 New 3 per cent. Stock, including Mrs. Jackson-Gwilt's gift (£300).

Astronomical and other MSS., Books, Prints, Instruments, &c.

Unsold Publications of the Society.

Three Gold Medals.

Report of the Auditors.

We, being two of the duly appointed Auditors, beg to lay before this General Meeting of the Royal Astronomical Society the following Report:—

1. We have examined the Treasurer's account, and an account of the assets and property of the Society, and have found and certified the same to be correct.

2. The receipts and expenditure for the past year are as stated in the Treasurer's account.

3. The cash in hand on December 31, 1882, including the balance at the bankers', amounted to 549*l.* 10*s.* 7*d.*

4. The funded property is the same as at the end of last year, and in addition, a sum of 500*l.* has been placed on deposit account at the bankers'. The books, instruments, and other effects have been examined and found in a satisfactory condition, so far as their safe keeping is concerned.

5. We have laid on the table a list of the names of those Fellows who are now in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

F. C. Penrose.
Robt. J. Lecky.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	6	...	XXVI.	177	...
I. Part 2	42	...	XXVII.	431	...
II. Part 1	55	...	XXVIII.	390	...
II. Part 2	20	...	XXIX.	417	...
III. Part 1	67	1	XXX.	166	...
III. Part 2	87	1	XXXI.	147	1
IV. Part 1	81	3	XXXII.	164	...
IV. Part 2	91	3	XXXIII.	169	1
V.	109	4	XXXIV.	169	6
VI.	127	3	XXXV.	112	5
VII.	153	3	XXXVI. (with M.N.)	206	11
VIII.	129	3	XXXVI. (without)	1	...
IX.	137	3	XXXVII. Part 1	350	8
X.	150	...	XXXVII. Part 2	298	8
XI.	157	...	XXXVIII.	288	2
XII.	164	...	XXXIX. Part 1	261	4
XIII.	173	1	XXXIX. Part 2	266	5
XIV.	374	3	XL.	291	3
XV.	143	...	XLI.	447	2
XVI.	170	1	XLII.	257	5
XVII.	153	2	XLIII.	268	3
XVIII.	153	...	XLIV	255	3
XIX.	157	...	XLV.	313	2
XX.	158	...	XLVI.	356	5
XXI. Part 1	314	...	XLVII. Part 1	12	...
XXI. Part 2	99	...	XLVII. Part 2	12	...
XXI. 1 & 2 (together)	64	1	XLVII. Part 3	33	...
XXII.	159	...	Index to *Memoirs*	652	1
XXIII.	153	1			
XXIV.	161	1			
XXV.	172	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	74	...	XXIII.	30	...
II.	76	1	XXIV.	23	...
III.	...	...	XXV.	7	...
IV.	...	...	XXVI.	10	...
V.	...	...	XXVII.	3	...
VI.	42	...	XXVIII.	74	...
VII.	2	...	XXIX.	55	1
VIII.	140	2	XXX.	67	3
IX.	23	2	XXXI.	98	1
X.	175	1	XXXII.	122	6
XI.	186	2	XXXIII.	104	2
XII.	12	2	XXXIV.	83	2
XIII.	151	3	XXXV.	66	3
XIV.	109	3	XXXVI.	39	...
XV.	126	2	XXXVII.	41	4
XVI.	109	3	XXXVIII.	104	3
XVII.	136	1	XXXIX.	106	2
XVIII.	166	...	XL.	118	2
XIX.	58	...	XLI.	125	6
XX.	30	...	XLII.	127	8
XXI.	18	...	Index to *Monthly Notices*	588	...
XXII.	33	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLII. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
" 2. The *Owen* portable circles, by Jones.
" 3. The *Beaufoy* circle.
" 4. The *Beaufoy* transit instrument.
" 5. The *Herschel* 7-foot telescope.
" 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich.

No. 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) $4\frac{6}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; double-image micrometer; two other micrometers; object-glass micrometer; one terrestrial and ten astronomical eyepieces, applied by means of two adapters; equatoreal stand, and clock movement.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of

Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

No. 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to $10''$.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon, and stand.

„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches: tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square: one beam compass.

„ 62. (36) A pentagraph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

„ 67. (41) Varley stand for telescope.

„ 69. (43) Telescope, with the object-glass of rock crystal.

„ 70. Portable equatoreal stand.

„ 71. Portable altazimuth tripod.

„ 72. Four polarimeters.

„ 74. Registering spectroscope, with one large prism.

„ 76. Two five-prism direct-vision spectroscopes.

„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.

„ 79. Spectroscope.

„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

„ 81. A back-staff, or Davis' quadrant.

„ 82. A nocturnal or star dial.

„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.

„ 84. A Hollis observing chair.

„ 85. Double image micrometer, by Troughton and Simms.

„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

„ 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.

No. 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

„ 90. An Arabic celestial globe of bronze, not quite 6 inches in diameter.

„ 91. Astronomical time watchcase, by Professor Chevallier.

„ 92. 2-foot protractor, with two moveable arms, and vernier.

„ 93. Beam compass, in box.

„ 94. 2-foot navigation scale.

„ 95. Stand for testing measures of length.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

„ 97. 12-cell Leclanché battery.

„ 98. 2 feet 6 inch navy telescope with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.

„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.

„ 100. 9-inch transit instrument, with level and iron stand.

„ 101. Small equatoreal sight instrument, by G. Adams, London.

„ 102. Sun-dial, by Troughton.

„ 103. Sun-dial, by Casella.

„ 104. Sun-dial.

„ 105. Box sextant, by Troughton and Simms.

„ 106. Prismatic compass, by Schmalcalder, London.

„ 107. Compass, by C. Earle, Melbourne.

„ 108. Prismatic compass, by Negretti and Zambra.

„ 109. Dipleidoscope, by E. Dent.

„ 110. Abney level, by Elliott.

„ 111. Pocket spectroscope, by Browning.

„ 112. Small brass astrolabe.

„ 113. Double sextant, by Jones.

„ 114. Two models, illustrating the effects of circular motions.

„ 115. A cometarium.

„ 116. A pair of 18-inch globes.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
" 23. The *Matthew* transit, to Captain Noble.
" 74. Registering spectroscope, with prism, to Mr. Lecky.
" 75. One five-prism direct vision spectroscope, to Colonel de Rottenburg.

From the *Sheepshanks* collection:—

No. 30. (4) 3¼-inch equatoreal and stand, to Mr. Sadler.
" 34. (8) Transit instrument, to the Rev. Professor Pritchard.
" 69. (43) Telescope, with rock-crystal object-glass, to Dr. Huggins.

The telescope and eyepieces of No. 29 (3), and the portable equatoreal stand No. 70, which were lent to the Transit of *Venus* Committee, and were used in observing the Transit at Bermuda, were lost in the S.S. "City of Brussels," on January 7, 1883.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Dr. B. A. Gould for his *Uranometria Argentina*. The President will lay before the Society the grounds upon which this award has been founded.

Publications of the Society.

Vol. XLVII. of the *Memoirs* is in course of publication. It will contain the following papers:—

Professor C. Pritchard. On the Moon's Photographic Diameter, and on the Applicability of Celestial Photography to Accurate Measurement.

Observations of the Transit of *Venus*, 1874, December 8–9, made in Victoria, New South Wales, South Australia, at Mooltan, and at the Cape of Good Hope.

H. C. Russell. Measures of Sir John Herschel's Cape Stars, together with a List of new Double Stars.

S. W. Burnham. Double-star Observations made in 1879 and 1880 with the 18½-inch Refractor of the Dearborn Observatory, Chicago.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—C. E. Burton.
Rev. J. Challis.
A. Cooper.
W. A. Cross.
H. Dodgson.
Rev. W. H. Drew.
S. Heywood.
R. C. May.
E. H. Pringle.
Rev. T. R. Robinson.
Prof. H. J. S. Smith.
C. V. Walker.
T. Warner.
Major-Gen. W. K. Worster.

Associates :—E. Plantamour.
J. F. K. Zöllner.

CHARLES E. BURTON was the son of the Rev. E. Burton, Rector of Rathmichael, in County Dublin. He graduated at Trinity College, Dublin, and was for some years the assistant to the Earl of Rosse at Parsonstown, where he learned the rudiments of the art of speculum-grinding, in which he afterwards became proficient, some of his specula, silver on glass, of from 6 to 15 inches diameter, being unsurpassed. Their excellence, as well as Mr. Burton's skill in delineating, is shown by the views of *Mars* lately published by the Royal Irish Academy. The observations on which the views were founded were made with 8- and 12-inch specula, which were wholly the work of Mr. Burton's own hands. Very shortly before his death he was engaged in taking photographs of the Moon directly enlarged by means of an eyepiece. For this purpose he employed the $7\frac{1}{2}$-inch Equatorial of his friend Dr. Erck, with an inch eyepiece. The diameter of the Moon's disk thus directly enlarged was about 10 inches, and the exposure from 8 to 16 seconds. His experiments in this direction were interrupted by his preparations for the Transit of *Venus* Expedition to the Cape of Good Hope. He died suddenly on July 9, 1882, from heart disease, at the early age of thirty-five. The number of the *Monthly Notices* for last June contains two short papers by him, which are dated June 5 and 6, 1882. He also at one time paid considerable attention to the question of earth currents in telegraph wires, and contributed two papers to the *Philosophical Transactions*, in which observations made on the South Eastern Railway were discussed, and the results compared with the

magnetic changes observed at the Greenwich Observatory. He was elected a Fellow of the Society on May 8, 1874.

JAMES CHALLIS was the fourth son of Mr. John Challis, of Braintree, Essex, where he was born on December 12, 1803. He first went to Braintree school, where, as he used often to say himself, he soon learned all that they could teach him. He then went for a short time to a small school kept in Braintree by the Rev. Daniel Copsey, who was afterwards author of *Essays on Moral and Religious Subjects* (1821), *Studies in Religion* (1826), and other works. Seeing his talent Mr. Copsey, in conjunction with Mr. Matthews, vicar of Coggeshall, sent him to try for a presentation to Mill Hill School, near London, which he succeeded in obtaining by examination. Before proceeding to the University he read for a time with Mr. Matthews.

In October 1821 he entered Trinity College, Cambridge, as a sizar. He was elected a scholar in 1824, and in 1825 he graduated as senior wrangler, being also first Smith's prizeman. The same tripos list contains the name of Sir J. W. Lubbock, whose researches in the Lunar Theory are well known. In the following year Challis was elected Fellow of Trinity, and he resided in the college until he was ordained in 1830, when he was presented to the college living of Papworth Everard, which he held until 1852. He held no college office except during the last two years of his residence, when he took part in the college examinations. The vacations he spent with pupils in the Isle of Wight, Wales, and the English Lakes, once also visiting France. In 1831 he vacated his Fellowship by marriage with the widow of Mr. Daniel Copsey, second daughter of Mr. Samuel Chandler, of Tyringham in Buckinghamshire. He was re-elected Fellow of Trinity in 1870, and was a Fellow at the time of his death.

On February 2, 1836 he was elected Plumian Professor of Astronomy and Experimental Philosophy in the University, in succession to Professor Airy, who had been appointed Astronomer Royal. Mr. Challis was also at the same time made Director of the Cambridge Observatory, where he resided for the next five-and-twenty years, diligently engaged in making and reducing astronomical observations, and where he dispensed, in conjunction with Mrs. Challis, a kindly hospitality that is well remembered by Cambridge men of that time. He resigned the directorship of the Observatory in 1861, when he was succeeded by Professor Adams; but he retained the Plumian Professorship and resided in Cambridge till his death. From 1843 until within the last three or four years he always lectured on Practical Astronomy and the Use of Astronomical Instruments, and when his health became impaired and he was no longer able to lecture himself, he appointed as his deputy Mr. Freeman, late Fellow of St. John's College, who lectured for him on these subjects. Professor Challis was a man of kindly disposition and of simple and courteous manners. His strength gradually

declined in the last few years of his life, and during the last year he was very weak, and it seemed as if death might come at any moment. He quietly passed away on Sunday, December 3, 1882, when within a few days of completing his seventy-ninth year. He was buried on Friday, December 8, at the Mill Road Cemetery, Cambridge, in the same grave with his wife.

Professor Challis was one of those who played a conspicuous part in what is not only the most important episode in the short history of the Cambridge Observatory, but perhaps the most striking event in the long records of Astronomy itself—the discovery of the planet *Neptune*. It is true that the planet was actually discovered at Berlin through Leverrier's predictions, quite independently of what had taken place at Cambridge, but it is true also that Adams had predicted the planet's place, and that Challis, looking in the place predicted, had actually twice seen the planet through the Northumberland Equatorial at Cambridge six weeks before the Berlin telescope was ever directed to the sky to look for it. The accidental possession of one of Bremiker's star-maps enabled Dr. Galle to detect the planet on the night on which he began the search; but the systematic and excellent method followed by Challis must soon have led to its discovery. It is difficult, perhaps, not to feel some regret that one who was so nearly successful, and who so well deserved success, should not have been enabled to announce to the world the actual discovery, and that the greatest of the triumphs of the Newtonian principles should not have been absolutely completed in the University where they had their birth; but so far from attributing any trace of blame to Professor Challis, one can scarcely admire too highly the zeal, industry, and conscientiousness which he brought to bear upon a research quite without precedent in the history of astronomy. He fully recognised the importance of the question, and showed no want of faith in the results obtained by refined and laborious analytical processes. On the contrary, he took every measure to secure the success of his undertaking, and success must have rewarded his efforts, had not their continuance been suddenly rendered unnecessary. The history of the discovery of the planet *Neptune* is given in three papers, all read before the Society on November 13, 1846, and printed in Vol. XVI. of the *Memoirs*. The first by the Astronomer Royal, which is entitled "Account of some Circumstances historically Connected with the Discovery of the Planet exterior to *Uranus*," appeared also in vol. vii. of the *Monthly Notices*. In the second Professor Challis gives an account of his observations at the Cambridge Observatory for the purpose of detecting the planet, and the third is Professor Adams's own paper, containing his mathematical investigations.*

* To secure more speedy publication, this paper was also issued with the *Nautical Almanac* for 1851, and copies of it were circulated with the number of the *Astronomische Nachrichten* for March 27, 1847.

The following *résumé* of the events relating to the investigations that preceded the discovery of the planet has been principally derived from these papers. It is well known that there were matters which gave rise to controversy at the time, but these are not referred to in what follows, only the essential facts being given. It is scarcely necessary to state that there is absolutely no doubt that the investigations of Adams and Leverrier were quite independent.

In 1841, Adams, then an undergraduate at St. John's College in his second year, formed the design of investigating the inequalities in the motion of *Uranus* that were still unaccounted for, as soon as he should have taken his degree. He graduated as senior wrangler in 1843, and at once attacked the problem. In February 1844 he asked Professor Challis to obtain from Mr. Airy, the Astronomer Royal, the errors in the tabular geocentric longitudes of *Uranus* for 1818–1826, with the factors for reducing them to errors of heliocentric longitude. These Professor Challis applied for, and the Astronomer Royal forwarded to him all the heliocentric errors of *Uranus* in longitude and latitude from 1754 to 1830. In September 1845, Adams called upon Professor Challis, and gave him a paper containing numerical values of the mean longitude at a given epoch, longitude of perihelion, eccentricity, mass and geocentric longitude of the new planet. On September 22, 1845, Professor Challis wrote a letter of introduction to the Astronomer Royal, beginning: "My friend Mr. Adams, who will probably deliver this note to you, has completed his calculations respecting the perturbation of the orbit of *Uranus* by a supposed ulterior planet, and has arrived at results which he would be glad to communicate to you, if you could spare him but a few moments of your valuable time." Adams called at Greenwich in September and October, but on neither occasion was he successful in seeing Mr. Airy, who at the time of the first visit was absent in France. At his second visit he left a paper, giving the following values of the mass and the orbit of the new planet:—

Mean Distance (assumed nearly in accordance with Bode's law)	38·4
Mean Sidereal Motion in 365·25 days	1° 30′·9
Mean Longitude, 1845, Oct. 1	323 34
Longitude of Perihelion	315 55
Eccentricity	0·1610
Mass (that of the Sun being unity)	0·0001656

This was accompanied by the list of the residual errors from 1690 to 1840, when the disturbance of the new planet was taken account of, the errors being very small, except in the case of Flamsteed's observation of 1690.

Some months later, in the number of the *Comptes Rendus*

for June 1, 1846, Leverrier gave reductions of the existing observations of *Uranus*, and concluded that the observations were irreconcilable with theory, and that there was no other possible explanation of the discrepancy except that of a disturbing planet exterior to *Uranus*. He investigated the elements of the orbit of such a planet, its mean distance being assumed to be double that of *Uranus*, and its orbit being in the plane of the ecliptic. The value of the mean distance was suggested by Bode's law. Leverrier gave, as the most probable result of his investigations, that the true longitude of the disturbing planet for the beginning of 1847 must be about 325°, and that an error of 10° in this place was not probable. No elements of the orbit or mass of the planet were given. On July 9, 1846, Mr. Airy wrote to Professor Challis from the Deanery, Ely, suggesting that search should be made for the planet with the Northumberland Equatorial, and offering the services of an assistant; and on July 13 he transmitted to him certain suggestions with regard to the proposed sweeps for the planet. On July 18, Professor Challis wrote to the Astronomer Royal: "I have only just returned from my excursion. . . . I have determined on sweeping for the hypothetical planet. . . . With respect to your proposal of supplying an assistant I need not say anything, as I understand it to be made on the supposition that I decline making the search myself. . . . I purpose to carry the sweep to the extent you recommend." On August 7 Professor Challis wrote to Mr. Main, in the supposed absence of the Astronomer Royal, saying that he had undertaken the search for the new planet, and that he had made trial of two methods of observing. In the one recommended by Mr. Airy he had met with a difficulty, as he had anticipated, and he had therefore adopted another method.

On September 2 Professor Challis wrote to Mr. Airy: "I have lost no opportunity of searching for the planet; and, the nights having been generally pretty good, I have taken a considerable number of observations: but I get over the ground very slowly, thinking it right to include all stars to 10–11 magnitude; and I find that to scrutinise thoroughly in this way the proposed portion of the heavens will require many more observations than I can take this year." On the same day (September 2) Adams wrote to the Astronomer Royal a letter, the opening paragraphs of which are as follows: "In the investigation the results of which I communicated to you last October, the mean distance of the supposed disturbing planet is assumed to be twice that of *Uranus*. Some assumption is necessary in the first instance, and Bode's law renders it probable that the above distance is not very remote from the truth: but the investigation could scarcely be considered satisfactory while based on anything arbitrary; and I therefore determined to repeat the calculation, making a different hypothesis as to the mean distance. The eccentricity also resulting from my former calculations was far too large to

be probable; and I found that, although the agreement between theory and observation continued very satisfactory down to 1840, the difference in subsequent years was becoming very sensible, and I hoped that these errors as well as the eccentricity might be diminished by taking a different mean distance. Not to make too violent a change, I assumed this distance to be less than the former value by about $\frac{1}{30}$th part of the whole. The result is very satisfactory, and appears to show that, by still further diminishing the distance, the agreement between the theory and the later observations may be rendered complete, and the eccentricity reduced at the same time to a very small quantity. The mass and the elements of the orbit of the supposed planet, which result from the two hypotheses, are as follows :—

	Hypothesis I. $\left(\frac{a}{a'}=0{\cdot}5\right)$	Hypothesis II. $\left(\frac{a}{a'}=0{\cdot}515\right)$
Mean Longitude of Planet, 1846, Oct. 1 ...	325° 8′	323° 2′
Longitude of Perihelion	315° 57′	299° 11′
Eccentricity	0·16103	0·12062
Mass (that of Sun being 1)	0·00016563	0·00015003

He also adds the errors of mean longitude, exhibiting the difference between theory and observation on the two hypotheses, and after pointing out that the errors given by the Greenwich Observations of 1843 are very sensible on both hypotheses, he proceeds: "By comparing these errors it may be inferred that the agreement of theory and observation would be rendered very close by assuming $\frac{a}{a'}=0{\cdot}57$, and the corresponding mean longitude on October 1, 1846, would be about 315° 20′, which I am inclined to think is not far from the truth. It is plain, also, that the eccentricity corresponding to this value of $\frac{a}{a'}$ would be very small." In consequence of the divergence of the results Adams asked for two normal places near the oppositions of 1844 and 1845. In the Astronomer Royal's absence these were sent by Mr. Main; and on September 7 Adams wrote: "I hope by to-morrow to have obtained approximate values of the inclination and longitude of the node."

But on August 31 Leverrier's second paper on the place of the disturbing planet had been communicated to the French Academy. The number of the *Comptes Rendus* containing this paper could not reach this country until the third or fourth week in September, and it does not appear that any earlier notice of its contents was received in England.

The elements given by Leverrier are—

Semi-axis Major	36·154 $\left(\text{or } \frac{a}{a'} = 0{\cdot}531\right)$
Periodic Time	217·387
Eccentricity	0·10761
Longitude of Perihelion	284° 45′
Mean Longitude, 1847, Jan. 1	318° 47′
Mass	$= \frac{1}{9300} = 0{\cdot}0001075$
True Heliocentric Longitude, 1847, Jan. 1	326° 32′
Distance from the Sun	33·06

Leverrier gave also comparisons between theory and observation, and he concluded that the planet would have a visible disk and sufficient light to make it conspicuous in ordinary telescopes.

In a letter received at Berlin on September 23, Leverrier invited Dr. Galle to search for the planet, suggesting that it might be recognised by its disk. The same evening Dr. Galle examined the heavens, comparing the stars with Dr. Bremiker's map (Hora xxi. of the Berlin Academy's Star Maps). He soon found a star of about the eighth magnitude, nearly in the place pointed out by Leverrier, which did not exist in the map. There could be little doubt that this was the new planet, and the observations of the two days following showed that its motion was nearly the same as that of the planet predicted. The finding of the planet was due to Dr. Bremiker's map: the disk could not easily be recognised before its existence was known.

It seems but just to Professor Challis that the following report, which he drew up for the Cambridge Observatory Syndicate, and which was printed at the time by them, should now be placed permanently on record as giving his own account of the circumstances attending the search for the planet at Cambridge. The report is dated December 12, 1846, and the preamble, which is signed by the syndics, runs: "The syndicate appointed to visit the Observatory, conceiving the subject at the present time to possess peculiar interest, beg leave to submit to the Senate the following statement of Professor Challis, describing the course of observations, founded on the theoretical calculations of Mr. Adams, of St. John's College, and made at the Observatory with a view to the discovery of the new planet." Professor Challis's report is as follows:—

"At a meeting of the Observatory Syndicate, held at the Observatory on December 4, for the despatch of ordinary business, a strong desire having been expressed by the Vice-Chancellor and the members of the Syndicate generally, to receive from me a Special Report of Observatory proceedings

relating to the newly-discovered Planet, drawn up in such a manner, and in such detail, as would enable them to lay complete information on the subject before the members of the Senate, I considered it to be my duty at once to comply with this request. A new body of the solar system has been discovered, by means depending on the farthest advances hitherto made in theoretical and practical astronomy, and confirming, in a most remarkable manner, the theory of universal gravitation. It is, therefore, on every account desirable that the members of the Senate should be made fully acquainted with the part which has been taken by the Cambridge Observatory, relatively to this important extension of astronomical science. The observations I shall have to speak of, and the reasons for undertaking them, are so closely connected with theoretical calculations performed by a member of this University, to account for anomalies in the motion of the planet *Uranus*, that the history of the former necessarily involves that of the latter. I hope that for this reason, and because of the peculiar nature of the circumstances, I may be allowed to make a communication less formal and restricted in its character, than a mere Report of Observatory proceedings.

"The tables with which the observations of the planet *Uranus* have been uniformly compared, were published by A. Bouvard in 1821. They are founded on a continued series of observations extending from 1781, the year of its discovery, to 1821. Previous to 1781, it had been accidentally observed seventeen times as a fixed star, the earliest observation of this kind being one by Flamsteed in 1690. Bouvard met with a difficulty in forming his Tables. On an attempt to found them upon the ancient, as well as the modern, observations, it appeared that the theoretical did not agree with the observed course of the planet. He thought this might be attributed to the imperfection of the ancient observations, and consequently rejected all previous to 1781, in the formation of the Tables finally published. These Tables represent well enough the observations in the forty years from 1781 to 1821; but very soon after the latter year, new errors began to show themselves, which have gone on increasing to the present time. It was now evident that the ancient observations had been rejected on insufficient grounds, and that from some unknown cause the theory was in fault. Were the Tables calculated inaccurately? The difference between observation and theory (amounting in 1841 to 96″ of geocentric longitude) was too great, and Bouvard's calculations were made with too much care to allow of this explanation. The effect of small terms neglected in the calculation of the perturbations caused by *Jupiter* and *Saturn*, could not be supposed to bear any considerable proportion to the observed amount of error. This state of the theory suggested to several astronomers the idea of disturbances, caused by an undiscovered planet more distant than *Uranus*. But there is no evidence of this hypothesis having been put to the test of calculation pre-

vious to 1843. The usual problem of perturbations is to find the disturbing action of one body on another, by knowing the positions of both. Here an inverse problem, hitherto untried, was to be solved; viz. from known disturbances of a planet in known positions, to find the place of the disturbing body at a given time. Mr. Adams, Fellow of St. John's College, showed me a memorandum made in 1841, recording his intention of attempting to solve this problem as soon as he had taken his degree of B.A. Accordingly, after graduating in January 1843, he obtained an approximate solution by supposing the disturbing body to move in a circle at twice the distance of *Uranus* from the Sun. The result so far satisfied the observed anomalies in the motion of *Uranus*, as to induce him to enter upon an exact solution. For this purpose he required reduced observations made in the years 1818–1826, and requested my intervention to obtain them from Greenwich. The Astronomer Royal, on my application, immediately supplied (February 15, 1844), all the heliocentric errors of *Uranus* in longitude and latitude, from 1754 to 1830, completely reduced. Mr. Adams was now furnished with ample data from observation, and his next care was to ascertain whether Bouvard's theoretical calculations were correct enough for his purpose. He tested the accuracy of the principal terms of the perturbations caused by *Jupiter* and *Saturn*, and concluded that the small terms which Bouvard had not taken into account would not sensibly affect the final results, the chief of them being either of long period or of a period nearly equal to that of *Uranus*. Besides which he introduced into the theory several corrections which had been derived from observation and calculation by different astronomers since 1821. The calculations were completed in 1845. In September of that year, Mr. Adams placed in my hands a paper containing numerical values of the mean longitude at a given epoch, longitude of perihelion, eccentricity of orbit, mass, and geocentric longitude, September 30, of the supposed disturbing planet, which he calls by anticipation 'The New Planet,' evidently showing the conviction in his own mind of the reality of its existence. Towards the end of the next month, a communication of results slightly different was made to the Astronomer Royal, with the addition of what was far more important, viz. a list of the residual errors of the mean longitude of *Uranus*, for a period extending from 1690 to 1840, after taking account of the disturbing effect of the supposed planet. This comparison of observation with the theory implied the determination of *all* the unknown quantities of the problem, both the corrections of the elements of *Uranus* and the elements of the disturbing body. The smallness of the residual errors proved that the new theory was adequate to the explanation of the observed anomalies in the motion of *Uranus*, and that as the error of longitude was corrected for a period of at least 130 years, the error of radius vector was also corrected. As the calculations rested on an

assumption, made according to Bode's law, that the mean distance of the disturbing planet was double that of *Uranus*, without the above-mentioned numerical verification, no proof was given that the problem was solved or that the elements of the supposed planet were not mere speculative results. The earliest evidence of the complete solution of an inverse problem of perturbations is to be dated from October 1845.

"Although the comparison of the theory with observation proved synthetically that the assumed mean distance was not very far from the truth, it was yet desirable to try the effect of an alteration of the mean distance. Mr. Adams accordingly went through the same calculations as before, assuming a mean distance something less than the double of that of *Uranus*, and obtained results which indicated a better accordance of the theory with observation, and led him to the conclusion, which has since been confirmed by observation, that the mean distance should be still farther diminished. This second solution taken in conjunction with the first may be considered to relieve the question of every kind of assumption. The new elements of the disturbing body, and the results of comparing the observed with the theoretical mean longitudes of *Uranus*, were communicated to the Astronomer Royal at the beginning of September 1846. These were accompanied by numerical values of errors of the radius vector, the Astronomer Royal having inquired, after the reception of the first solution, whether the error of radius vector, known to exist from observation, was explained by this theory. It would be wrong to infer that Mr. Adams was not prepared to answer this question till he had gone through the second solution. Errors of radius vector were as readily deducible from the first solution as from the other.

"The preceding details are intended to point out the circumstances which led astronomers to suspect the existence of an additional body of the solar system, and the theoretical reasons there were for undertaking to search for it. No one could have anticipated that the place of the unknown body was indicated with any degree of exactness by a theory of this kind. It might reasonably be supposed, without at all mistrusting the evidence which the theory gave of the *existence* of the planet, that its position was determined but roughly, and that a search for it must necessarily be long and laborious. This was the view I took, and consequently I had no thought of commencing the search in 1845, the planet being considerably past opposition at the time Mr. Adams completed his calculations. The succeeding interval to midsummer of 1846 was a period of great astronomical activity, the planet *Astræa*, Biela's double comet, and several other comets, successively demanding attention. During this time I had little communication with Mr. Adams respecting the new planet. Attention was again called to the subject by the publication of M. Leverrier's first researches in the *Comptes Rendus* for June 1, 1846. At a meeting of the Green-

wich Board of Visitors held on June 29, at which I was present, Mr. Airy announced that M. Leverrier had obtained very nearly the same longitude of the supposed planet as that given by Mr. Adams. On July 9 I received a letter from Mr. Airy, in which he suggested employing the Northumberland Telescope in a systematic search for the planet, offering at the same time to send an assistant from Greenwich, in case I declined undertaking the observations. This letter was followed by another dated July 13, containing suggestions respecting the mode of conducting the observations, and an estimation of the amount of work they might be expected to require. In my answer, dated July 18, I signified the determination I had come to of undertaking the search. Various reasons led me to this conclusion. I had already, as Mr. Adams can testify, entertained the idea of making these observations; the most convenient time for commencing them was now approaching; and the confirmation of Mr. Adams's theoretical position by the calculations of M. Leverrier appeared to add very greatly to the probability of success. I had no answer to make to Mr. Airy's offer of sending an assistant, as I understood the acceptance of it to imply the relinquishing on my part of the undertaking.

"I have now to speak of the observations. The plan of operations was formed mainly on the suggestions contained in Mr. Airy's note of July 13. It was recommended to sweep over, three times at least, a zodiacal belt 30° long and 10° broad, having the theoretical place of the planet at its centre; to complete one sweep before commencing the next; and to map the positions of the stars. The three sweeps, it was calculated, would take 300 hours of observing. This extent of work, which will serve to show the idea entertained of the difficulty of the undertaking before the planet was discovered, did not appear to me greater than the case required. It will be seen that the plan did not contemplate the use of hour XXI. of the Berlin Star Maps, the publication of which was equally unknown at that time to Mr. Airy and myself. It may be proper here to explain that the construction of a good star-map requires a great amount of time and labour both in observing and calculating, and that precisely this sort of labour must be gone through to conduct a search of the kind I had undertaken. The stars must first be mapped before the search can properly be said to begin. With a map ready made, the detection of a moving body, as it happened in this instance, might be effected on a comparison of the heavens with the map by mere inspection. Not having the advantage of such a map, I proceeded as follows. I noted down very approximately the positions of all the stars to the 11th magnitude that could be conveniently taken as they passed through the field of view of the telescope, the breadth of the field with a magnifying power of 166 being 9′, and the telescope being in a fixed position. When the stars came thickly, some were necessarily allowed to pass without recording their places. Wishing to

include *all* stars of the 11th magnitude, I proposed, in going over the same region a second time, to avail myself of an arrangement peculiar to the Northumberland Equatorial, the merit of inventing which is due to Mr. Airy. The Hour-circle, Telescope, and Polar Frame are movable by clockwork, which may be regulated to sidereal time nearly. While this motion is going on, the Telescope and Polar Frame are movable *relatively to the Hour-circle*, by a tangent-screw apparatus, and a handle extending to the observer's seat. This contrivance enables the observer to measure at his leisure differences of Right Ascension however small, and therefore meets the case of stars coming in groups. The observations made by this method might include all the stars it was thought desirable to take, and therefore might include *all* the stars taken in the first sweep. The discovery of the planet would result from finding that any star in the first sweep was not in its position in the second sweep. If two sweeps failed in detecting the planet among the stars of the first sweep, it might be among the stars of the second, which would be decided by taking a third sweep of the same kind as the second. It will appear that this plan carried out would not only detect the planet if it were in the region explored, but would also, in case of failure, enable the observer to pronounce that it was not in that region. The second mode of observing required the aid of my two assistants, Mr. Morgan and Mr. Breen, in reading off and recording the observations.

"I commenced observing July 29, employing on that day the first method, with telescope fixed. The next day I observed according to the second method, with telescope moving. On August 4, the telescope was fixed as to Right Ascension, but was moved in Declination in a zone of about 70′ breadth, the intention of the observations of that day being to record points of reference for the zones of 9′ breadth. On August 12, the fourth day of observing, I went over the same zone, telescope fixed, as on July 30 with telescope moving. Soon after August 12, I compared, to a certain extent, the observations of that day, with the observations of July 30, taken with telescope moving; and finding, as far as I carried the comparison, that the positions of July 30 included *all* those of August 12, I felt convinced of the adequacy of the method of search I had adopted. The observations were continued with diligence to September 29, chiefly with telescope fixed, and were made early in Right Ascension for the purpose of exploring as large a space as possible before I should be compelled to desist by the approach of daylight. On October 1 I heard that the planet was discovered by Dr. Galle, at Berlin, on September 23. I had then recorded 3150 positions of stars, and was making preparations for mapping them. The following results were obtained by a discussion of the observations after the announcement of the discovery.

"On continuing the comparison of the observations of July 30 and August 12, I found that No. 49, a star of the 8th magnitude

in the series of August 12, *was wanting in the series of July* 30. According to the principle of the search, this was the planet. It had wandered into the zone in the interval between July 30 and August 12. I had not continued the former comparison beyond No. 39, probably from the accidental circumstance that a line was there drawn in the memorandum-book in consequence of the interruption of the observations by a cloud. After ascertaining the place of the planet on August 12, I readily inferred that it was also among the reference stars taken on August 4. Thus, after four days of observing, two positions of the planet were obtained. This is entirely to be attributed to my having, on those days, directed the telescope towards the planet's theoretical place, according to instructions given in a paper Mr. Adams had the kindness to draw up for me. I would also beg to call attention to the fact that, after August 12, the planet was discoverable by a closet-comparison of the observations, a method of observing, depending on novel and ingenious mechanism, having been adopted, by which I could say of each star, to No. 48, 'This is not a planet,' and of No. 49, 'This *is* a planet.' I lost the opportunity of announcing the discovery by deferring the discussion of the observations, being much occupied with reductions of comet observations, and little suspecting that the indications of theory were accurate enough to give a chance of discovery in so short a time. On September 29 I saw, for the first time, the communication presented by M. Leverrier to the Paris Academy on August 31. I was much struck with the manner in which the author limits the field of observation; and with his recommending the endeavour to detect the planet by its disk. Mr. Adams had already told me that, according to his estimation, the planet would not be less bright than a star of the ninth magnitude. On the same evening I swept a considerable breadth in Declination, between the limits of Right Ascension marked out by M. Leverrier, and I paid particular attention to the physical appearance of the brighter stars. Out of 300 stars, whose positions I recorded that night, I fixed on one which appeared to have a disk, and which proved to be the planet. This was the third time it was observed before the announcement of the discovery reached me. This last observation may be regarded as a discovery of the planet, due to the good definition of the noble instrument which we owe to the munificence of our Chancellor.

"From the reduced places of the planet, on August 4 and August 12, and from observations since its discovery extending to October 13, Mr. Adams calculated, at my request, values of its heliocentric longitude at a given epoch, its actual distance from the Sun, longitude of the node, and inclination of the orbit, which were published as early as October 17. I am now diligently observing the planet with the meridian instruments, and when daylight prevents its being seen on the meridian, I propose carrying on the observations as long as possible with the

Northumberland Equatorial, for the purpose of obtaining data for a further approximation to the elements of the orbit.

"My report of proceedings relating to the planet here terminates. I beg permission to add a few remarks, which the facts I have stated seem to call for. It will appear by the above account, that my success might have been complete, if I had trusted more implicitly to the indications of the theory. It must, however, be remembered, that I was in quite a novel position: the history of astronomy does not afford a parallel instance of observations undertaken entirely in reliance upon deductions from theoretical calculations, and those too of a kind before untried. As the case stands, a very prominent part has been taken in the University of Cambridge, with reference to this extension of the boundaries of astronomical science. We may certainly assert to be facts, for which there is documentary evidence, that the problem of determining, from perturbations, the unknown place of the disturbing body, was first solved here; that the planet was here first sought for; that places of it were here first recorded; and that approximate elements of its orbit were here first deduced from observation. And that all this may be said, is entirely due to the talents and labours of one individual among us, who has at once done honour to the University, and maintained the scientific reputation of the country. It is to be regretted that Mr. Adams was more intent upon bringing his calculations to perfection, than on establishing his claims to priority by early publication. Some may be of opinion, that in placing before the first astronomer of the kingdom results which showed that he had completed the solution of the problem, and by which he was, in a manner, pledged to the production of his calculations, there was as much publication as was justifiable on the part of a mathematician whose name was not yet before the world, the theory being one by which it was possible the practical astronomer might be misled. Now that success has attended a different course, this will probably not be the general opinion. I should consider myself to be hardly doing justice to Mr. Adams, if I did not take this opportunity of stating, from the means I have had of judging, that it was impossible for any one to have comprehended more fully and clearly all the parts of this intricate problem; that he carefully considered all that was necessary for its exact solution; and that he had a firm conviction, from the results of his calculations, that a planet was to be found."

With regard to the disk of the planet, Encke, in his account of the discovery by Dr. Galle in Vol. xxv. (col. 52) of the *Astronomische Nachrichten*, writes: "Erlauben Sie mir nur hinzuzufügen, dass die Auffindung so schnell bloss durch die vortreffliche akademische Sternkarte von Bremiker möglich war. Eine Scheibe lässt sich erst erkennen, wenn man weiss dass es seyn wird." Bremiker's star-map, Hora xxi., was communicated to

the Berlin Academy on December 9, 1844, and it was lying for correction at the Berlin Observatory when Leverrier's letter was received (*Monthly Notices*, vol. xxxviii. p. 151).

Professor Challis published a second report to the Syndicate, dated March 22, 1847, relating to the subsequent observations of the new planet, but this need not be further referred to here, as it was reprinted in the *Astronomische Nachrichten* (vol. xxv., col. 309). The more Professor Challis's part in the history of the planet is examined, the more highly one appreciates his assiduity and zeal. He seems to have throughout done all in his power to encourage and assist Adams in his investigations, and it was through no fault of his that the honour of discovering a planet whose existence had been thus predicted does not belong to this country.

At the second return of Biela's comet since it was discovered to be periodic, in 1826, and the eleventh of its returns since it was first observed in 1772, it was found to have divided into two. It was observed by Encke on December 21, 1845, at Berlin, and by Valz, on December 25, at Marseilles; but no trace of separation was then noticed. In Europe the existence of two separate nuclei was first observed and announced by Professor Challis. In a letter to the President of the Society, printed in vol. vii. pp. 73, 74, of the *Monthly Notices*, he wrote:—"On the evening of January 15, when I first sat down to observe it, I said to my assistant, 'I see *two* comets.' However, on altering the focus of the eye-glass and letting in a little illumination, the smaller of the two comets appeared to resolve itself into a minute star, with some haze about it. I observed the comet that evening but a short time, being in a hurry to proceed to observations of the new planet [*Astræa*]. On first catching sight of it on this evening (Jan. 23), I again saw two comets. Clouds immediately after obscured the comet for half an hour. On resuming my observations I suspected at first that both comets had moved. This suspicion was afterwards confirmed: the two comets have moved in equal degree, retaining their relative positions. . . . . What can be the meaning of this? Are they two independent comets? or is it a binary comet? or does my glass tell a false story? I incline to the opinion that this is a binary or double comet, on account of my suspicion on Jan. 15. But I never heard of such a thing. I am anxious to know whether other observers have seen the same thing. . . . In the meanwhile I thought, with the evidence I have, I had better not delay giving you this information." In a subsequent letter he wrote:—"There are certainly two comets. . . . . I think it can scarcely be doubted, from the above observations, that the two comets are not only apparently, but really, near each other, and that they are physically connected. When I first saw the smaller on Jan. 15, it was faint, and might easily have been overlooked. *Now* it is a very conspicuous object, and a telescope of moderate power will readily exhibit the most singular phenomenon that has occurred for many years—a double

comet!" It appears that M. Wichmann, at Königsberg, observed the comet on the 14th, but saw nothing of the companion: there was, however, some vapour in the air. On January 15, the same night as that on which Professor Challis saw the two comets, the air being purer and the moon not risen, he saw the companion comet immediately with a power of 45. The duplication of the comet had, however, been previously observed at Washington by Lieutenant Maury, Director of the Naval Observatory, who "discovered during his observations on Jan. 13th a nebulous-looking object altogether cometary in its appearance, preceding Biela's comet by nine or ten seconds in the lower part of the field of view." On the 14th "both objects had increased about three minutes in Right Ascension since the night before" (*Monthly Notices*, vii. pp. 74, 90).

Professor Challis communicated his observations of the two heads of the comet to Adams, who calculated their orbits. The relative positions of the two heads formed the subject of Adams's first communication to the Society (March 13, 1846).

The comet at its return in 1852, when the distance between the nuclei was about eight times as much as before, was again observed by Professor Challis. Neither comet was seen in 1859 or 1866, and the remarkable circumstances relating to their supposed connection with the meteor shower of November 27, 1872, are too well known and too recent to need notice here (see *Monthly Notices*, vol. xxxiii.). Remarkable as the Cambridge observations of the Comet in January 1846 seemed to be at the time, its subsequent history has given even additional interest to them.

During the twenty-five years in which Professor Challis directed the Cambridge Observatory he was a very accurate and assiduous observer, making great use of the Northumberland Equatorial, and his contributions to the publications of the Society and to the *Astronomische Nachrichten* are very numerous. He also paid great attention to instrumental improvements, and to him is due the introduction in its present form of the collimating eyepiece, an instrument now so generally used that it is worth while to reproduce here the account he gives of it in his *Lectures on Astronomy* (p. 69):—

"This important auxiliary instrument, which enables the observer to obtain instrumental corrections exclusively by optical means, was the invention of Bohnenberger, of Tübingen, who has given a description of it in the *Astronomische Nachrichten* (Band iv., 1826, col. 327–336). My attention was first called to it by Henderson, late Astronomer Royal at the Cape of Good Hope, who brought me a specimen (made apparently according to the above-mentioned description), having a metallic reflector with a hole at the centre, through which the wires and their reflected images were looked at with a Ramsden Eyepiece. On trial I found this construction to be extremely inconvenient, on account of the limited field of view and the small interval between

the eye-glass and the wires, rendering it difficult to hold a lamp for throwing light upon the reflector. On mentioning these circumstances to the late William Simms, he constructed for me the instrument represented by Figs. 19 and 20, in which a three-glass eyepiece is substituted for the Ramsden Eyepiece, and for the metallic reflector a piece of plate-glass, the reflection from which, as will presently be explained, gives the means of seeing the wires, together with their reflected images, with quite sufficient distinctness. By these changes the above-stated inconveniences were entirely removed. As far as I am aware, the collimating eyepiece has since been uniformly made according to this pattern. I brought it into use in the Cambridge Observatory in the year 1850; the next year it was adopted at Greenwich when the new Transit Circle was first made use of. It had already attracted the attention of Bessel, Gauss, and Lamont, but had not, I believe, been definitively employed for exact determinations relating to meridian observations with the Transit instrument and Mural Circle before I made such application of it at the Cambridge Observatory."

He also invented the Transit-Reducer, a machine for calculating the formula

$$(a + b \cos z + \sin z)\frac{\operatorname{cosec} \delta}{15},$$

the total value of which is given by a single operation. The instrument which he used in the Cambridge Observatory was shown in the Great Exhibition of 1851, and received the award of a bronze medal. The machine is described in vol. x. of the *Monthly Notices*, and also on pp. 387–390 of his *Lectures*.

Another mechanical contrivance to which he devoted much attention was connected with his method of correcting the errors due to the forms of the pivots of a Transit instrument. The method which involved the use of the collimating eyepiece is described in vol. xix. of the *Memoirs*. Mention should also be made of the "Meteoroscope," an instrument invented by him for the purpose of rapidly determining the altitude and azimuth of any point of the heavens at which a meteor appeared. This instrument was a good deal used at Cambridge.

In the twenty-five years, 1836–61, during which Professor Challis was director of the Observatory, he published vols. ix.–xix. of the *Cambridge Observations*; vol. xx., which contained the observations for the years 1855–1860, was published by him in 1864, in accordance with the arrangement made when he retired from the directorship in 1861, by which he undertook the superintendence of the reduction and publication of the remainder of the observations made prior to 1861. On the Introductions to the different volumes of the *Cambridge Observations* he bestowed great pains and attention; the Introductions to those for 1836 and 1837 contain a detailed description of the methods of observing with the meridian instruments.

In the first years of his Professorship he lectured upon Hydrodynamics, Pneumatics, and Optics with special reference to the mathematical theories of Light and Sound; the leading facts were exhibited experimentally, and explanations were given of the principles employed in the mathematical reasoning. He published a Syllabus of these lectures in 1838. In 1843, when he had been director of the Observatory for seven years, he began a course of lectures on Astronomy and Astronomical Instruments, and this course he continued to give regularly, without interruption, until, as has already been stated, within the last few years. The Syllabus of these lectures, which he published in 1843, bears the title "A Syllabus of Lectures on Practical Astronomy and Astronomical Instruments: to which is added a list of Formulæ used in the Reduction of Astronomical Observations." Towards the close of his life he arranged his lectures in a form suitable for publication, and they were issued from the University Press at Cambridge in 1879, under the title "Lectures on Practical Astronomy and Astronomical Instruments." The volume contains 400 pages, and on every page of it there is evidence of the author's efforts to attain accuracy and his careful attention to *minutiæ* in all that concerns the instruments of an Observatory. It has special reference to the Cambridge instruments, and was intended mainly for use in the University; but he writes in the preface: "Although the instruments of the Cambridge Observatory and processes of observation I adopted in the use of them, have been more especially described, and the treatise consequently partakes somewhat of a local and personal character, I may venture, I think, to say that as having been written after twenty-five years of continuous labour in astronomical observations and calculations, and containing what may have occurred to me in the course of that experience as contributory to the advancement or improvement of practical astronomy, it will be found of some general utility as respects the work carried on in an Astronomical Observatory." All who attended Professor Challis's lectures will feel satisfaction that they are now placed on record. For nearly fifty years no one could have been more faithful than he was to the study of practical astronomy in the University.

Professor Challis wrote several papers on points connected with the integration of the equations in the Lunar Theory, which appeared in the *Philosophical Magazine* for 1854 and 1855, and a memoir on the Problem of Three Bodies, which was printed in the *Philosophical Transactions* for 1856. The first of the papers in the *Philosophical Magazine* (April 1854) was originally communicated to the Cambridge Philosophical Society, and was reported upon unfavourably by Professor Adams. In the number of the *Philosophical Magazine* for June 1854 Professor Challis invited Professor Adams to discuss with him its merits, and accordingly in the July number Professor Adams gave in detail the reasons for his disapproval of the new theorems contained in the paper. It is only fair to Professor Challis to men-

tion the handsome manner in which, fifteen years afterwards, in the introduction to his "Notes on the Principles of Pure and Applied Calculation," he acknowledges the justice of this criticism. He admits that the unfavourable report of the paper was made to the Council "not without reason; for it was a premature production, and had in it much that was insufficiently developed, or entirely erroneous. . . . . Theorem II. was wholly erroneous;" and he proceeds: "In my reply in the August number I said much in the heat of controversy that had better not have been said, and some things, also, that were untrue." He states further that when he found the discussion had not settled the matter, he pursued the inquiry in a series of communications, "which will at least attest the diligence with which I laboured to get at the truth of the question."

Before leaving the astronomical writings of Professor Challis, it is interesting to notice that the earliest of all his papers was astronomical, its object being to investigate an extension of Bode's law to the case of the satellites of the planets. It was read before the Cambridge Philosophical Society so long ago as December 8, 1828, and is printed in vol. iii. of their *Transactions*.

Professor Challis was the author of numerous papers on Hydrodynamics, Heat, Light, the Theory of Colours, &c. His Report on the State of Hydrodynamics—perhaps the best known of his mathematical papers—appeared in the British Association volume for 1833. It was in order to be enabled to devote more time to the development of his theories of mathematical physics that he resigned his charge of the Observatory. His "Notes on the Principles of Pure and Applied Calculation, and Applications of Mathematical Principles to Physics," is a large volume of 700 pages, which was published in 1869. He states that 112 pages were printed in 1859, when he was compelled to desist from it by the pressure of his occupations at the Observatory. After remarking that he holds it to be indisputable that physical science is incomplete till experimental inductions have been accounted for theoretically, and that the completion of a physical theory demands mathematical reasoning, he proceeds, "When according to the best judgment I could form respecting the applications which the results of my hydrodynamical researches were capable of, I seemed to see that no one was as well able as myself to undertake this necessary part in science, I gave up (in 1861) my position at the Observatory, under the conviction, which I expressed at the time, that I could do more for the honour of my University and the advancement of science by devoting myself to theoretical investigations than by continuing to take and reduce astronomical observations after having been thus occupied during twenty-five years. The publication of this work will enable the cultivators of science to judge whether in coming to this determination I acted wisely. Personally I have not for a moment regretted the course I took; for although it

has been attended with inconveniences arising from the sacrifice of income, I felt that what I could best do, and no one else seemed capable of undertaking, it was my duty to do. It should, farther, be stated that after quitting the Observatory, and before I entered upon my theoretical labours, I considered that I was under the obligation to complete the publication of the meridian observations taken during my superintendence of that institution. This work occupied me till the end of 1864, and thus it is only since the beginning of 1865 I have been able to give undivided attention to the composition of the present volume."

He subsequently published "An Essay on the Mathematical Principles of Physics with reference to the study of physical science by candidates for mathematical honours in the University of Cambridge" (108 pp., 1873), and "Remarks on the Cambridge Mathematical Studies and their relation to modern physical science" (93 pp., 1875).

Much that he wrote, especially on Hydrodynamics, did not receive acceptance from other mathematical physicists. He devoted his life with great assiduity and constancy to the search for philosophical truth, endeavouring to carry out Newton's principles. Although personally he was modest in the extreme, yet he was so earnest in his views and held such strong convictions as to the mode in which philosophical inquiries should be carried out that his language sometimes became almost self-assertive. In a letter to Whewell (1863) he wrote: "It has been the business of my life to endeavour to reach 'the second main series of physical discovery' in the direction that Newton indicated. Accordingly, I have adopted implicitly his 'foundation of all philosophy,' including therein his views expressed at the end of the *Principia* respecting the action of a 'very subtle spirit' (the ether) which 'pervades dense bodies,' and to the agency of which he attributes the phenomena of light, heat, electricity, &c. In conjunction with the Newtonian ideas I have taken advantage of the modern advancement in pure analysis, and in particular have applied partial differential equations in determining the motions and dynamical action of the supposed ether. It is marvellous how readily the results so obtained, taken in connection with the Newtonian properties of matter, adapt themselves to the solution of the great problems of Natural Philosophy. And yet none of my mathematical contemporaries have taken the same course, and I seem to remain the sole representative of the spirit of the Newtonian philosophy." He was so gentle in his character and his life was so simply and unselfishly devoted to the search after truth, that it is all the more matter for regret that the exceptional character of some of his views rendered part of his work of doubtful scientific value.

As Plumian Professor he was examiner for the Smith's Prizes, and he examined without intermission from 1836 to 187[illegible] set long papers, and he took great trouble [illegible]

a very remarkable series, and afford a perfect record of the matters that occupied his attention in all these years. Not only were the papers well suited to their purpose, but they possessed considerable interest of their own; and this is especially true, perhaps, of some of the earlier and simpler questions in each paper. The papers are to be found in the University Calendars for the different years; he had thoughts of reprinting them, in which case they would have formed an interesting and remarkable volume, but he abandoned the idea.

He was also author of the following works:—"Creation in Plan and in Progress: being an essay on the first chapter of Genesis" (1861); "A Translation of the Epistle of the Apostle Paul to the Romans, with an Introduction and Critical Notes" (1871); "An Essay on the Scriptural Doctrine of Immortality" (1880); "The Counting and Interpretation of the Apocalyptic 'number of the Beast'" (1881).

He was elected a Fellow of this Society on April 8, 1836, and of the Royal Society on June 9, 1848.

He leaves one son and one daughter. His son, Mr. James Law Challis, was appointed in 1860 to the Rectory of Papworth Everard, which had been held by his father from 1831 to 1852, and in 1878 he was presented by the Council of this Society to the Vicarage of Stone in Buckinghamshire, of which they were then the patrons. J. W. L. G.

Henry Dodgson, M.D., of Derwent House, Cockermouth, was born at Mockerkin, in Cumberland, on March 27, 1833, and was the youngest son of Isaac Dodgson, Esq. He chose the medical profession, and studied at the Universities of Edinburgh and Paris, graduating M.D. at Edinburgh in 1856. Since then he has practised in Cockermouth, and ultimately succeeded to one of the most extensive practices in the neighbourhood, where he was widely respected and esteemed. In 1866 he was proposed by the late Isaac Fletcher, F.R.S., M.P., and elected a Fellow of this Society. At that time he gave much of his time to observations in astronomy, and had an Observatory with a good telescope erected at considerable cost. But latterly, owing to the death of his partner and the calls of a large practice, he was obliged to relinquish a study he had a great love for. He, however, found time to be interested in the great educational movements of the day, and some years ago was elected Chairman of the School Board, which office he held up to the time of his death. He was a Fellow of the Meteorological Society, and took regular meteorological observations, which were published in the Registrar-General's reports. He died, after a fortnight's illness, of pneumonia, followed by typhoid fever. In 1866 he married his partner's niece (daughter of the late Edward Hughes, Esq., F.R.G.S., Head Master of the Royal Naval School, Greenwich) by whom he had nine children, who, with his widow, [illegible] him.

Robert Charles May was born at Ampthill, in Bedfordshire, on April 5, 1829. His father, Mr. Charles May, F.R.S., was a partner in the firm of Ransomes & May, of Ipswich, and it was in the works of that well-known engineering firm that Mr. Robert May served his apprenticeship; after which time he held the post of out-door manager, a position that gave him great experience as a mechanical engineer in the erection of steam mill-machinery, as well as in that of fixed plant on railways, such as iron aqueducts, roofs, bridges, &c. Afterwards he had charge of the works other than rolling stock on the South Eastern Railway. Leaving this position in 1852, he was associated with the late Mr. J. M. Rendel, F.R.S., in some of the hydraulic works of that eminent engineer. He constructed, in 1853, the outfall of the Walland and Denge marshes at Jury's Gut, or Jew's Gap, in Kent, and placed there a reservoir or tidal pen, at the sea end of which were draw-gates, and at the land end self-acting tidal doors. The tidal water was thus penned in, and formed a sufficient scour to keep the outfall clear of the shingle and sand which travel from west to east with the tide on that coast. In 1854, about three years after his father had left Ipswich and settled in London as a consulting engineer, he followed his father's example, and soon acquired a very considerable practice in gas, mill, and railway engineering, and was largely employed as superintendent engineer in the construction of fixed and moving railway plant for home and foreign railways.

As an arbitrator in engineering disputes he had a very large experience, and was almost without a rival, for he put his whole heart into whatever he undertook, and brought sound mechanical knowledge of a high order, with an exceptionally clear and analytical judgment, to bear upon the questions with which he had to deal. His high integrity and fairness commanded the esteem of both sides, and gave considerable weight to his decisions. He had also a very large experience in valuation work.

In his later years he devoted some attention to mining work, and in the last two or three years of his life he held the appointment of consulting engineer to the Gallizzi Sulphur Mines in Sicily, and he was lately appointed to a similar position in the Giona mines in the same island. These appointments necessitated his travelling to the Mediterranean twice a year, and it was on his return from Sicily, and immediately on his arrival at his hotel at Marseilles, that he was seized with the illness (aneurism of the heart) which in a few minutes terminated his life, on July 20, 1882.

He was a Member of the Institution of Civil Engineers, and an old Member of the Institution of Mechanical Engineers. He was also also one of the Assessors of the Board of Trade. He was elected a Fellow of the Society on May 10, 1861.

Edward Hamilton Pringle, the fifth son of the late Mark Pringle, formerly of Oakendean, Karsham, and J.P. and D.L. for

Sussex, was born January 1, 1844, at Oakendean. He was educated chiefly at the Edinburgh Academy and Edinburgh Military Academy. In 1864 he went out to Queensland, and was engaged in sheep-farming in that colony for two years. He then proceeded to India, where Lord Napier of Ettrick, at that time Governor of Madras, conferred on him the appointment of Assistant Engineer in the Public Works department. After holding successively the posts of Special Executive Engineer of Wainád, District Engineer of South Kanara, and Divisional Officer of the West Coast, he was gazetted to Ganjám; and at Berhampúr, in that district, he was seized with cholera on May 30, 1882, and expired after a few hours' illness.

He was devoted to scientific pursuits from his boyhood, and, in addition to his astronomical attainments, was an acute and careful naturalist. He applied himself chiefly to spectral astronomy, but was unfortunate in being long stationed on the hills of Malabar, which for months together are enveloped in clouds and mist, and are otherwise unsuited for observations save at rare intervals. His health was moreover much shattered by fever contracted in the jungles of Wainád, and of late years the pressure of official duties allowed him scant time for the pursuit of his favourite science.

Mr. Pringle was a not unfrequent contributor to the pages of *Nature* on astronomical and zoological questions, and in 1877 published a small pamphlet on the subject of forests in relation to famines, a matter which has since then engaged much attention in India.

He was elected a Fellow of the Royal Astronomical Society on April 10, 1874; he was also a Fellow of the Royal Geographical Society and a Member of the Society of Telegraph Engineers.

THOMAS ROMNEY ROBINSON, D.D., F.R.S., was born in Dublin on April 23, 1792. His abilities and genius seem to have been manifested at a very early age, and his first appearance as an author dates so far back as 1806. On that occasion his venture was entitled "Juvenile Poems by Thomas Romney Robinson, to which is prefixed a short account of the Author by a Member of the Belfast Literary Society": Belfast, 1806. The book contains a number of poems written by the author at various ages below thirteen. Dr. Robinson's last publication is in the *Philosophical Transactions* for 1880, and it must be regarded as a curious circumstance in literary history that an interval of three-quarters of a century should have elapsed between Dr. Robinson's first appearance as an author and his last.

In the year 1814 Dr. Robinson was elected a Fellow of Trinity College, Dublin, and he was for several years engaged in lecturing in the University as Deputy Professor of Natural Philosophy. In connection with his labours as a teacher he

published in 1820 a volume entitled *A System of Mechanics for the Use of Students in the Dublin University.*

After a residence for nine years at Dublin University, Dr. Robinson accepted the living of Enniskillen, which was in the gift of Trinity College. Robinson's career in the University was thus finished the year before Humphrey Lloyd, the late Provost, was elected to a fellowship. Dr. Robinson did not long remain Rector of Enniskillen. In the year 1824 he exchanged the living of Enniskillen for that of Carrickmacross; and of his ecclesiastical career there is little further to note, except that about half a century later (in the year 1872) he was nominated a Prebendary of St. Patrick's Cathedral, Dublin, and that several of his sermons have been published.

Dr. Robinson is principally known to fame by his connection with the Armagh Observatory. The Observatory at Armagh was founded in 1793 by Primate Robinson. The endowment of the Observatory, as well as that of a public library, arose out of Primate Robinson's scheme of forming at Armagh a university which might serve for the education of the North of Ireland. It is needless to say that the greater part of the Primate's beneficent scheme was never realised. At his death the meridian instruments he had ordered for the Observatory seem to have been countermanded by his heirs. The two following Primates had but little interest in science, and it was not until they were succeeded by Lord John George Beresford, the late Primate, that any further steps were taken. Primate Beresford presented to the Observatory a Transit Instrument, a Mural Circle, and an Equatorial Reflector of fifteen inches aperture. The first of these was erected in 1827, and the last in 1835. It was in the year 1824 that Dr. Robinson was appointed Director of the Armagh Observatory. He threw himself into the work of practical astronomy with the greatest zeal and success, and the celebrated Armagh Catalogue is a noble monument of his assiduity and skill. This catalogue, though not published until 1859, contains many observations of stars between the years 1830–40, of which we possess few contemporary observations. On this account the Armagh Catalogue has a distinct value, and it has been much used by Argelander in his investigations of the proper motion of 250 stars in vol. vii. of the Bonn Observations. It may be mentioned that a note by Dr. Robinson giving the places of three stars, which were affected with errors in the Armagh Catalogue, appeared in the *Monthly Notices* as recently as last March; it was read at the meeting at which his death was announced. The Mural Circle at Armagh was subsequently furnished with a new telescope having an objective of seven inches aperture, and with this 1000 of Lalande's stars, nearly all between 6·0 and 7·5 magnitude, were re-observed in 1868-76, and the results have been published in the *Transactions* of the Royal Dublin Society, new series, vol. i.

Dr Robinson's determination of the Constant of Nutation also

deserves notice, though, for reasons which need not now be discussed, it has never come into practical use among astronomers.

The celebrated cup anemometers, now so extensively used, are an indication of the practical skill and ingenuity by which Dr. Robinson was distinguished. The very latest scientific labour of his long life was a redetermination of the constants of the cup anemometer. This was accomplished by experiments on a very large scale, in the dome of Mr. Grubb's workshops, at Dublin. The results of these labours have been published in the *Phil. Trans.*, 1878–1880.

Considering that Dr. Robinson was an author before the battle of Trafalgar, that he was elected a Fellow of Trinity College, Dublin, before the battle of Waterloo, and that he was made Director of the Armagh Observatory within a year or two of the death of Sir W. Herschel, it is not surprising to find that his scientific friends and associates belonged mainly to the past generation. In that past generation, Dr. Robinson occupied a distinguished and remarkable position. He was intimately associated with the late Earl of Rosse in all those memorable experiments which culminated in the great Reflector at Parsonstown. He was the friend of Sir James South, of Sir William Fairbairn, and of many other celebrities. His wide sympathy, his gentle and invariable kindness, his wondrous stores of knowledge, his charming powers of conversation, his brilliant eloquence, were qualities universally recognised, and caused him to be welcomed and beloved in many circles besides those purely scientific.

He was elected a Fellow of the Society on May 14, 1830.

R. S. B.

Charles Vincent Walker died at his residence at Tunbridge Wells, on the morning of December 24, 1882, in the seventy-first year of his age. He had been Telegraph Engineer to the South Eastern Railway since 1845, and was one of the oldest telegraph engineers in the country. He was a zealous worker in the science of electricity, and was the inventor of several useful appliances in connection with telegraphy, including the instruments by which the block system on railways is worked. His name is especially associated with the origin of the distribution of time by telegraph. On May 10, 1849, Mr. Glaisher wrote to Mr. Walker that he wished to talk with the latter about the laying down of a wire from the Observatory to the Lewisham Station, and on May 23 following, the Astronomer Royal gave Mr. Walker a brief sketch of the use to be made of the wire referred to, his scheme, as he stated, being "the transmission of time by galvanic signal to every part of the kingdom in which there is a galvanic telegraph from London." It was proposed to lay four wires underground from the Royal Observatory to the railway station at Lewisham, and to extend them to London Bridge. The South Eastern Railway Company gave every

facility. On September 16, 1852, an electric clock at London Bridge Station was erected, and connected by wire with an electric clock at the Royal Observatory, Greenwich. The first time-signal sent from the Royal Observatory was received at London Bridge Station at 4 p.m. on August 5, 1852; and on August 9, 1852, Dover received a time-signal for the first time from the Royal Observatory direct, and it was made visible at certain first-class stations between London and Dover. After that the system rapidly spread, its success depending greatly on the scientific skill and zeal of Mr. Walker.

He was elected a Fellow of the Royal Society in 1855, and he was a late President of the Meteorological Society, and of the Society of Telegraph Engineers. He was elected a Fellow of the Society on January 8, 1858.

Emile Plantamour.—In the Annual Report of last year the death of Gautier was announced, and now we have to record the death of his pupil and successor as Professor of Astronomy and Director of the University at Geneva, which occurred on September 7, 1882. Plantamour was born at Geneva in 1815. He received his early education in the old college, founded by Calvin, after which he spent eight years in the then celebrated school of Hofroyl. In 1833 he entered the Geneva Academy, where he became one of Gautier's most promising pupils. After graduating in philosophy, he resolved to make the study of astronomy the work of his life, a design in which he was encouraged by Gautier, who promised to vacate his chair in Plantamour's favour when the latter had completed his university education. The chief reason—an affection of the sight—which caused Gautier to desire to retire from the direction of the Observatory was referred to in the obituary notice of Gautier. From Geneva Plantamour proceeded to Paris, where he studied for two years under Arago. He also was a pupil of Bessel at Königsberg, where, in 1839, he took the degree of doctor, the subject of his thesis being the methods of calculating the orbits of comets. From Königsberg he went to Berlin, and worked for some time with Encke, who recognised in his quickness of observation and aptitude for complex calculations his special fitness for the career to which he intended to devote himself. On his return to Geneva Plantamour received the double appointments of the professorship of Astronomy in the Academy, which has since been transformed into a University, and director of the Observatory. In 1848 he accepted also the chair of Physical Geography, and he retained all three positions until his health began to fail him a few months before his death. His publications chiefly related to atmospheric electricity, observations of comets, and meteorological observations made on the Great St. Bernard. Special reference should be made to the important investigations of the diurnal oscillations of the soil undertaken by him by means of spirit levels, and of which accounts are given in the *Comptes Rendus* for 1878

and 1879. Much of his time was devoted to meteorology, and his papers in the *Bibliothèque Universelle* on the subject were numerous; he was also one of the most active members of the Helvetic Scientific Society for the observation of atmospheric phenomena. He devoted attention to Geodesy, and in 1861 became the representative of Geneva on the Paris Geodetic Commission. He was also a useful member of the International Geodetic Association which met a few years ago at Geneva. In connection with the Genevan Society of Arts he organised a watch and chronometer competition, which has proved of great value to the staple industry of Geneva. Watches and chronometers are sent to the Observatory and tested there, the results being published, and prizes awarded to the best timekeepers. Four years ago he added to the observatory at his own expense a refractor of ten inches aperture, and he erected the building for its reception. He was a man of fortune, and might have devoted his life to social enjoyment and ease; but he was deeply attached to science, and preferred to retain his posts in the University, although the modest salary he received scarcely covered his expenses.

He was an honorary member of the Turin Academy, and a correspondent of the French Institute. He was elected an Associate of the Society on April 12, 1844.

JOHANN KARL FRIEDRICH ZÖLLNER was born at Leipzig on November 8, 1834, and died on April 25, 1882. In 1872 he was appointed Professor of Physical Astronomy in the University of Leipzig. He was the author of numerous papers in the *Berichte* of the Saxon Academy of Sciences, on subjects connected with Spectrum Analysis and the constitution of the Sun, and also of several larger works, the most important of which was published in 1865 under the title *Photometrische Untersuchungen.* Upon the same subject he also published his *Grundzüge zu einer allgemeinen Photometrie des Himmels.* His researches on the philosophy of space, and other subjects, with his theories of light and electricity, appeared in the three volumes of his *Wissenschaftliche Abhandlungen.* In 1872 he published his work *Ueber die Natur der Cometen,* upon a third edition of which he was engaged at the time of his death. He was the inventor of several appliances for spectroscopic and photometric researches He was elected an Associate of the Society on November 8, 1872.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories.

Royal Observatory, Greenwich.

The general meridian work at the Royal Observatory during the past year has gone on with the same regularity as in former years, special attention having been given to the observation of the Moon on every favourable opportunity throughout the lunation, and to the Sun, planets, and fundamental stars when they have passed the meridian before 15^h. The larger minor planets have also been observed about the time of opposition, when practicable. The Working Catalogue of 2600 stars, alluded to in former Reports, including all stars down to the fifth magnitude, and others required for various purposes, is now nearly cleared off, and a new Working Catalogue is in preparation, including all the stars down to the sixth magnitude contained in Dr. Heis's *Atlas Cœlestis*, which had not been previously observed at Greenwich with the Transit Circle. Comet *a* 1882 (Wells) has been observed twelve times on the meridian *sub polo*, and Comet *b* 1882 (the Great Comet) three times.

The mean error of the Moon's tabular R.A., from observation with the Transit Circle in 1882, is $+0^s \cdot 82$.

Two new determinations of the flexure of the Transit Circle were made in 1882, on January 2 and December 30, the resulting values being respectively $+0'' \cdot 03$ and $-0'' \cdot 07$. No correction for flexure, as determined by the collimators, has been applied to the observations.

In order to extend the range of the reflexion observations of stars, which, owing to the interference of the two collimators, had been hitherto limited to within an arc of 40° from the zenith, and thus to obtain data for determining the true law of the R−D discordance, a new arrangement of the mounting of the collimators was carried out in the summer of 1882, in which the collimators are mounted on upright arms turning about centres below. This allows them to be swung on one side when not in use, the piers being cut away so as to offer no obstruction to reflexion observations as far as Z.D. 71° on each side of the zenith. The importance of this extended range of reflexion observations is shown from an examination of the mean discordances of (R−D), which, for last year, steadily increase from

the zenith to Z.D. 70°, at which point the discordance between direct and reflexion observations amounts to 1″·6.

Notwithstanding this fundamental change in the mounting of the collimators, their stability from day to day is found not to be sensibly affected; but, as a matter of precaution, it is usual to place the corresponding wires of the north and south collimators in coincidence immediately before and after each determination of the collimation error of the Transit Circle. There is rarely any sensible difference between the two sets of readings.

With the Altazimuth the Moon has been observed at every practicable opportunity, on the same system as in former years, to the end of the lunation on 1882, July 9. Since this date the observations have been restricted to the first and last Quarters of each lunation, as it has been shown by a comparison of the number of observations made with the Transit Circle and Altazimuth, that the intermediate semi-lunation, before and after Full Moon, is well represented for all practical purposes by the daily observations made on the meridian. Advantage has been taken of this arrangement to devote greater attention to the observation of comets and other miscellaneous phenomena with the Equatorials, &c. In order to adopt the Altazimuth to the observation of comets, a new system of wires, having central cross wires thicker than the others, was inserted at the beginning of the present year.

Comet *a* 1882 (Wells) was observed on five days with the Naylor Equatorial, Comet *b* 1882 (the Great Comet) on eight days with the Sheepshanks Equatorial, and Comet *c* 1882 (Barnard) on one day with the S.E. Equatorial. Comet *b* was also observed on one day with the Altazimuth. The resulting apparent R.A. and N.P.D., together with the mean places of the comparison stars, are published in the *Monthly Notices* for November. Micrometric measures of the positions of six of the satellites of *Saturn—Enceladus*, *Tethys*, *Dione*, *Rhea*, *Titan*, and *Iapetus*—have also been made on several evenings with the S.E. and Sheepshanks Equatorials.

Twelve occultations of stars by the Moon have been observed in 1882, and also eighteen phenomena of *Jupiter's* satellites.

The solar eclipse of May 16 was favourably observed with the S.E. Equatorial, and four series of differences of R.A. and N.P.D. of the cusps and limbs were obtained. The plan of observation was so arranged as to give corrections to the tabular R.A. and N.P.D. of the Moon, and to the adopted semi-diameters of the Sun and Moon. During the eclipse, which at its greatest phase only covered 0·186 of the Sun's disk, eighteen differences of R.A. of cusps, ten differences of N.P.D. of limbs, and nine differences of N.P.D. of cusps, were observed. The times of the beginning and ending of the eclipse were also recorded by several observers.

The spectroscopic observations have been made as usual

with the "half-prism" spectroscope mounted on the S.E. Equatorial. The routine observations have been less numerous than usual, partly owing to the cloudy weather of the latter half of the year, and partly to the pressure on the Photographic department from the increase in the number and size of the Sun-spots as the period of maximum solar activity is approached. The spectra of various Sun-spots have been examined on ten days; the great Sun-spot of November last being especially remarkable for the instances of reversal of lines which it displayed. The examination of the chromosphere for prominences has been made on twenty-two days, and numerous prominences were seen on each occasion.

The displacement of the F or *b* lines has been measured in the spectra of thirty-one stars. This work has suffered some interruption during the period of observation of Comets *a* and *b*, the former of which was examined with the spectroscope on eight occasions, and the latter on three. The single-prism spectroscope has also been employed on one night for the measurement of the positions of the bands in the spectrum of *Uranus*, and the "experimental half-prism" spectroscope was employed on the night of November 17 in the examination of the spectrum of the Aurora. All the spectroscopic observations have been completely reduced to the end of 1882.

Photographs of the Sun have been obtained with the photoheliograph on 201 days during the year; whilst in 1881 they were taken on 173 days. This increase is due to arrangements having been made for securing photographs on Sundays. The increased number of photographs, and, still more, the remarkable increase in the number and size of the Sun-spots, have rendered the work of their measurement and reduction much more severe than in previous years. The reductions have, however, been considerably lightened, without any real loss of accuracy, by limiting the calculations to tenths of a degree instead of to minutes. The photographs have been measured in duplicate to the end of 1882, and completely reduced to 1882 October 8.

Arrangements have been made with the Solar Physics Committee by which the gaps in the Greenwich series of Sun-pictures will be filled up as far as possible by photographs taken at Dehra Dûn (India) and elsewhere, thus rendering the series practically continuous. Seventy-nine photographs dating from 1881 December 22, to 1882 June 30, have already been received from the Committee and of these thirty-six, up to 1882 March 8, have been measured in duplicate, and twenty-eight, up to 1882 February 20, have been completely reduced.

The reductions of the observations in every department are in a forward state, and the complete copy of the observational sections of the volume of *Greenwich Observations* for 1882 will shortly be ready for the printer. The printing of the *Greenwich Observations* for 1881 is nearly finished, the whole of the volume being in type, and it is hoped that it will be ready for distribu-

tion in the spring. The separate copies of the Results of the Spectroscopic and Photographic Observations for 1881 have been already distributed in advance of the volume.

Armagh Observatory.

By the Act of Parliament (Irish Statutes, 31 George III., ch. 46) "for settling and preserving a Public Observatory in the city of Armagh," the appointment of the Astronomer is vested in the Archbishop of Armagh, while the Observatory is under the control of a Board of Governors and Guardians, of whom the Primate is Chairman.

On February 28, 1882, the Rev. T. R. Robinson died, after having had charge of the Observatory for more than fifty-eight years. In June the Primate appointed Dr. J. L. E. Dreyer to succeed Dr. Robinson; but as extensive repairs to the dwelling-house were necessary, Dr. Dreyer did not take up his residence at the Armagh Observatory till August 31.

The principal instruments now in use are:—

1. A Mural Circle by Jones, with a telescope of seven inches aperture by T. Grubb, and two collimators.

2. A Chronograph by Knoblich (clock movement improved by Grubb).

3. A 15-inch Reflector by T. Grubb, mounted equatorially with clockwork; can be used either in the Newtonian or the Cassegrain form.

4. A 3·8-inch Refractor by Jones, on a portable Equatorial Stand.

5. Three Sidereal Clocks (one with barometer compensation); one Mean Time Clock.

The Transit Instrument, with which the R.A.'s of the Armagh Catalogue were determined, has not been in use for the last twenty years, but is in good order. A 12-feet Zenith Sector (formerly at Kew) has lately been dismounted. Besides several minor instruments (a sextant, two theodolites, &c.), there are a number of old instruments which now only possess historical interest.

Since 1864 the Mural Circle has been employed to determine the places of a number of stars from Lalande-Baily's Catalogue. Close upon 3,000 stars have been observed, most of them from three to five times. These are now being prepared for publication as a second Armagh Catalogue, for 1875, a grant having been obtained from the Royal Society for the purpose of printing this.

With the Reflector the ingress of *Venus* on the Sun's disk was successfully observed (see *Copernicus*, January 1883). If the steps which are now being taken to procure for the Observatory an Equatorial Refractor should prove successful, it is

intended to devote this instrument to micrometrical work, and probably to try Cluster Photography with the Reflector.

The self-recording meteorological instruments established in 1868 have been working without interruption.

By order of the Board of Governors a history of the Observatory has been drawn up, and is now about to be printed in pamphlet form.

Cambridge Observatory.

As in former years, our attention has been specially given to the Zone observations with the Transit Circle, and the reductions have been carried on with great assiduity. The True Right Ascensions and the True North Polar Distances are calculated up to the end of 1881, and Tables are in course of preparation, not only for reducing the places to the Mean Equinox at the beginning of each year, but also for again reducing these results to 1875·0, which is the epoch chosen by the German Astronomische Gesellschaft.

These observations have, however, on several occasions been interrupted by the fine comets which have recently attracted so much attention.

Comet *Wells*, 1882, was observed on twenty-four nights, from April 5 to May 31 inclusive, with the Northumberland Equatorial and Square Bar Micrometer, and fourteen times with the Transit Circle: and a very satisfactory parabolic orbit was obtained by Mr. Graham from the observations of April 5, 14, and 22.

The Great Comet 1882 (*b*) was compared 159 times with neighbouring stars from October 25 to December 6 inclusive.

All these observations have been reduced and communicated to the Royal Astronomical Society, with the exception of the fourteen meridian observations of the Comet *Wells*.

The bad weather entirely prevented any observation of the Transit of *Venus* being made at this Observatory.

Dunsink Observatory.

During the past year there has been a change here, owing to the appointment of Dr. J. L. E. Dreyer, to succeed the late Dr. Robinson at Armagh. The vacancy thus made has been filled by the appointment of Mr. Arthur A. Rambaut, of Trinity College, Dublin.

The Chronograph is now in good working order, and meridian observations of the selected list of stars are in progress (see Report last year). The Equatorial has, as before, been chiefly employed in researches on Annual Parallax. The series for Σ 2486=6 β *Cygni* has been completed and discussed, and the

result shows that this star has a parallax of $0''\cdot482 \pm 0''\cdot054$. The series of observations on *μ Cephei* has been finished, but the results are not yet ready for publication.

During the autumn, observations of *Victoria* and of *Sappho* were made in conjunction with those simultaneously made by Mr. Gill at the Cape for the determination of the Solar Parallax.

The Transit of *Venus* was seen to some extent. Clouds obscured the contacts, but micrometrical measures of the distances of the limbs were obtained.

Part IV. of our publications was distributed last year. Part V. has gone to the press. It will contain a detailed account of the Parallax work with the Equatorial.

Royal Observatory, Edinburgh.

The work of daily time-signals, by both ball, gun, and controlled clocks, with the necessary observations, have been carried on as usual through the past year; likewise the calculations of the bi-diurnal meteorological observations at 55 of the stations of the Scottish Meteorological Society, for the Registrar General of Scotland, and have been printed in his monthly and quarterly returns.

In the course of last July the Government made a grant of money towards binding the many unbound pamphlets belonging to the Observatory; and assured the Astronomer that they had the resumption of printing the Star Catalogue and the repair and completion of the instruments, as recommended by their Commissioners of Inquiry in 1876 and 1879, under their serious consideration.

Glasgow Observatory.

Apart from the ordinary operations connected with the transmission of Greenwich Mean Time to the city and port of Glasgow, there is only to report, in connection with the past year, the final passing through the press of the Glasgow Star Catalogue, which is expected to be ready for distribution in two or three weeks. The Glasgow Observatory was one of the few favoured places in the British Isles where an observation of the ingress of *Venus* on the Sun's disk was obtained on the 6th of December, 1882.

Kew Observatory.

Sun-spot observations on Hofrath Schwabe's method have been made on 197 days. The Sun's surface was found to be free from spots on three of those days.

A small portable $2\frac{3}{4}$-inch refracting telescope, with a magnifying power of 42 diameters, was used by the observer till July 3; since that date the observations have been made by means of the Photoheliograph, which was removed from the Loan Collection at South Kensington for that purpose, and reinstated on the pedestal in the Dome, a position which it occupied prior to its being sent to the Royal Observatory, Greenwich, in 1873.

The spots are now drawn by the observer, as they appear projected upon the focussing screen.

The measurements and reductions of Sun-spot positions and areas, as determined by means of the Kew Photoheliograph, from 1864 to 1872, having been completed for Mr. De La Rue, he has deposited the manuscript with the Council of the Royal Society.

Preparations were made with a view to obtain photographs of the Transit of *Venus*, but clouds prevented any being taken.

The usual magnetical and meteorological observations and reductions have been carried on as formerly.

Liverpool Observatory, Bidston, Birkenhead.

During the past ten years between two and three thousand chronometers have been tested at this observatory in three definite temperatures. The temperature is changed fifteen degrees at the end of each week in the following order: 55°, 70°, 85°, 70°, 55°. The object of changing the temperature in this way is to show the amount of variation in the rate due to change of temperature apart from the change of rate arising from other causes, and in this way to obtain the data necessary for calculating the corrections to the rates due to change of temperature by the formulæ published in the Report on this Observatory for 1872. The thermal factor ranges in different chronometers from about 0·001 to 0·004, the average being 0·0025. With this factor, when the maximum gaining rate is at 70°, the change of rate due to change of temperature between 40° and 100° is $2^s{\cdot}5$ a day; but if the temperature of maximum gaining rate should be 30° on either side, 70° the change of rate between 40° and 100° amounts to $9^s{\cdot}0$ a day. There is no difficulty in correcting the rates for error of thermal adjustment, and the change of rate arising from other causes can be detected and allowed for at sea by daily comparisons of the chronometers with each other, and by occasional observations of well-known points of land.

There are now deposited at this Observatory the records of upwards of one hundred voyages from Liverpool to and from the west coast of South America. Each ship carried three chronometers, and the Greenwich time, carried on by rates corrected for change of temperature, has been recorded daily

throughout each voyage. Numerous observations have also been made by the officers of the Pacific Steam Navigation Company for checking the chronometers at intervals during the voyage. The results show that by keeping such records it is practicable to render chronometric navigation sensibly perfect.

The meteorological observations obtained from the self-recording instruments have been tabulated, and telegrams have been sent daily to the Meteorological Office and to the Liverpool Underwriters' rooms.

Radcliffe Observatory, Oxford.

Observations have been systematically made with the Transit Circle throughout the year 1882.

The number of observations is as follows:—

Transits	2117
Circle Observations (each requiring the reading of the four microscopes)	2189

These totals include—

	In R.A.	In N.P.D.
Observations of Sun at Solstices and Equinoxes	32	29
Observations of Moon	54	56
Comet *a*, 1882	15	16
Reflexion Observations of Stars ...	—	109

and

162 pairs of Nadir Observations.

No opportunity was afforded of observing the time of passage of the Moon's diameter during the year, but 17 measures of the vertical diameter have been secured.

Two new wires were inserted by Mr. Simms on Oct. 2, and the equatorial intervals of the whole system have been carefully redetermined. An investigation of the flexure of the telescope has recently been made. The value found was almost identical with that which has been in use since 1880, June.

The current reductions are in a forward state, the N.P.D.'s being completely, and the R.A.'s very nearly, reduced up to date.

The Astronomical Results for 1880 have been printed.

The observations for 1881 have been discussed, and are being prepared for press. Following the plan adopted at the Cape, the Nadir Points have been exclusively determined with the Nadir reflecting eyepiece; but frequent observations of stars by reflexion, north and south of the zenith, have been made as a check upon the existence of any systematic errors.

From 27 Northern stars with 56 reflexion observations and 57 direct observations the value of R—D is

$$-0''.222;$$

whilst from 34 Southern stars with 77 reflexion observations and 108 direct observations the value of R—D is

$$+0''.013.$$

The mean discordance between the Nadir Points determined from the wire observations and from the star is therefore only

$$-0''.08.$$

The colatitude found from observations made during the year 1881 is

$$38^{\circ}\ 14'\ 25''.05;$$

but if the Nadir Points used had been those deduced from reflexion observations of stars alone, the colatitude would be

$$38^{\circ}\ 14'\ 24''.95.$$

The difference between these results is small, and the uncertainty of the colatitude determination of the year is therefore confined within very small limits.

A series of Northern stars which have been used in the determination of differences between the longitudes of the Cape Observatory and Aden have been under observation here at the request of Mr. Gill.

Seventeen observations of phenomena of *Jupiter's* satellites, seven of occultations of stars by the Moon, and the eclipse of the Sun on May 16 have been made with the extra-meridional instruments.

The Meteorological Results for 1880 have been printed and distributed, and those for 1881 are being discussed.

In addition to the regular work of the Observatory the grounds have been made available for the erection and trial of the instruments of the different Transit of *Venus* expeditions which were sent from this country, and for a comparison of the clock errors of the different observers with those of the Standard Sidereal Clock as determined by the Observatory staff.

The sky was clouded here generally during the time of the Transit, but a view of *Venus* well on the Sun was obtained during a short break in the clouds.

Oxford University Observatory.

The whole strength of the Observatory has been, without intermission, directed to the photometry of the brighter stars from the Pole to the Equator, including a few stars of inferior brightness, or of southern declination, but possessing interest. This work was substantially completed in December last; a few stars remaining for re-observation. Professor Pritchard has taken one of the two telescopes, and its photometer used for the above purpose, to Cairo, in order to complete the Memoir, in respect of the atmospheric and climatic effects on the apparent brilliancy of stars. The more interesting results of the general photometric work have been communicated to the Society during the past year.

In the *Memoirs* of the Society will be found a communication on the Photographic Diameter of the Moon, which, it is believed, establishes the applicability of photography to astronomical measurements of the most delicate character. There still remains in the Observatory a research, all but ready to be submitted to the Society, on the relative positions of the brighter stars in the group of the *Pleiades* observed with the Duplex Micrometer.

Arrangements were made for the observation of the Transit of *Venus* by several observers with telescopes of various apertures, but unfortunately without avail, owing to unfavourable weather. Notwithstanding the unpromising nature of the day, some fifty members of the University assembled at the Observatory, remaining there until sunset in patient hope of at least a glimpse of the planet on the Sun, which would have been exhibited after the manner of Horrox's historical method of projection.

It is right to acknowledge the continuance of the very cordial assistance of the Board of Visitors, and the zealous aid of the assistants, Mr. W. E. Plummer and Mr. Jenkins. The latter accompanies Professor Pritchard to Cairo; the former is left in charge of the Observatory during his absence.

Stonyhurst College Observatory.

During the past year the entire chromosphere has been measured on 70 different days. Two hundred and twenty-one drawings of the solar spots have been made in the usual manner, and several enlarged drawings of the more remarkable spots and groups have been made to a scale of 30 inches to the solar diameter.

The observations of *Jupiter's* satellites, and of occultations of stars by the Moon, have been continued as in previous years.

Owing to the badness of the weather, the position of Comet

b, 1882, was observed only a few times with the 8-inch Equatorial. Four transits of the comet across the meridian were observed.

The solar eclipse of May 16 was well observed both with the spectroscope and telescope.

Temple Observatory, Rugby.

The measurement of position and distance of double and multiple stars has been continued as usual during the past year, and 255 complete sets of measures of 105 stars have been made, so that each star has been measured on either two or three different nights.

The Observatory has been open on 77 nights, but in this are included a few cloudy ones, when opportunity was taken to go through the finding of instrumental errors with the most advanced boys.

Some attention has been given to the measurement of recession and approach of stars with the spectroscope on the Reflector, and the comet was observed several times, and drawings were made of it.

Mr. Percy Smith made some excellent drawings of the large Sun-spots in November.

Mr. Barclay's Observatory, Leyton, Essex.

The ordinary routine work has been carried on as usual. Measures of double stars and observations of planetary satellites have been made.

Mr. Talmage left, in October 1882, for Barbadoes, to observe the Transit of *Venus*, and will not return till the middle of February. During his absence only some meteorological work is carried on.

Mr. Campbell's Observatory, Arkley, Barnet.

The observations of the Moon are still continued at this Observatory, with a view to the determination of the distance of the Sun by means of the parallactic inequality.

This year's work has been much interrupted by an accident and by absence from home.

The analytical part is in a forward condition, as applied to the 134 observations taken before the end of 1882, and will, it is hoped, be still carried on by Mr. Neison.

Mr. Common's Observatory, Ealing.

During the past year the three-foot telescope has been chiefly used for photography.

The great difficulty of commanding a long exposure has been well got over by a special arrangement that gives an exposure for any desired time with small deviation from accuracy in following the image. It is quite probable that details in the fainter parts of nebulæ may now be photographed that would not be detected by eye-observation.

With this arrangement for exposing the plate, photographs of the great nebula in *Orion* have been taken, which in extent and amount of detail exceed expectations founded on the results of previous attempts.

On September 16, at $22^h\ 45^m$, a comet was found near the Sun with the helioscope erected in 1881. This proved to be the Great Comet of 1882, near perihelion. Photographs of the remarkable nucleus were obtained in the month of November, and a number of sketches made with the three-foot telescope.

Colonel Cooper's Observatory, Markree.

With the large Refractor the measures of double stars and of the diameters of planets were continued during the year. The Transit of *Venus* and other phenomena were observed.

The observations with the Meridian Circle were discontinued pending the construction of a new Standard Clock to mark the Chronograph. It was found that too much time was lost in signalling from the Sidereal Clock in the meridian-room, which was necessary on account of the badness of the clock that marked the prickers on the Chronograph.

The meteorological registers have been kept, as heretofore, by an assistant. They are the most complete registers in this country, with the exception of those obtained at the stations supplied with photographic self-recording instruments. As, however, the results furnished from the latter are not so trustworthy as those obtained by eye-observations of instruments properly exposed, it is contemplated to have the instruments read hourly for at least one year, as soon as the required sum of money is placed at the disposal of the Observatory. Some progress has been made in the reduction of the old registers.

The most important feature during the year's activity has been the addition of first-class Magnetical Instruments. The large Magnetometer did not arrive till the end of the year, but during the latter half of the year the Magnetic Dip was observed

every fortnight, and it is hoped that this part of the activity of the Observatory may be extended during the coming year.

Some time was also spent in gaining experience in photography, and a photographic eyepiece has been ordered for the large Refractor, with which it is intended to photograph Sun-spots and other phenomena.

A Rain-band Spectroscope was also added to the instrumental outfit during the autumn, as well as Browning's Solar Eyepiece.

The Earl of Crawford's Observatory, Dun Echt.

The greater number of the observations made at this Observatory during the past year, refer to comets.

Comet *Wells* was observed for place on ten nights, while its spectrum was examined on several occasions, and measured on five nights. This is the first comet which showed, besides the usual hydrocarbon bands, also the sodium lines. The presence of the latter in the spectrum was first noticed on May 27, but the real nature of the line was only recognised on the following night, when it was already much brighter, and found to coincide exactly with the sodium line of a spirit-lamp. Several attempts were made to find the comet at and after perihelion passage, but in vain.

The comet which seems only to have been seen during the total eclipse of the Sun on May 16, was also searched for in the twilight, but without success.

Also the attempts to find the Great Comet, notice of which had been telegraphed by M. Cruls, failed, and but for the telegram obligingly sent by Mr. A. A. Common it is not improbable that it might have escaped notice on Monday, September 18, although, with attention drawn to it, it was easily seen in spite of its nearness to the Sun. The spectroscopic observations secured on that day deserve mentioning. They prove also in this comet the presence of great quantities of sodium vapour, and, what is more important, they leave little or no doubt that also vast masses of iron vapour existed on that day in the comet, and moreover they furnish a splendid proof of Doppler's theory by the observed displacement of all the sodium and iron lines towards red. The unfavourable state of the weather permitted only on two other occasions measurements of the spectrum of this most interesting comet. The details of the spectroscopic observations were published in *Copernicus*.

Of Comet *Barnard*, 1882, only two places were secured.

The eclipse of the Sun on May 16 was observed both with 15·06-inch Grubb Refractor and with the 6-inch Simms Refractor.

With the 15·06-inch Refractor also a fairly satisfactory observation of the Transit of *Venus* was made.

Dr. Copeland having been appointed chief of the Government

Transit of *Venus* Expedition to Jamaica, the instruments and houses lent by Lord Crawford for the expedition were put into good order during the summer, and other necessary preparations made. Dr. Copeland, having started from Dun Echt on October 7, and obtained good observations of the Transit of *Venus* at Jamaica, is expected to return in a few months.

During the year twenty-three Circulars—Nos. 45 to 67—all printed at the Observatory, were distributed. With the exception of No. 53 they all relate to comets. Besides observations they contain fifteen sets of elements and about the same number of ephemerides. Nearly all the telegraphic informations, received and sent, were transmitted by the "Science Observer Code," which answers its purpose admirably. In spite of the inevitable mutilations of some of the words, every message could be perfectly deciphered.

The reductions of the observations are in a forward state.

Considerable progress has been made in the printing of observations connected with the Transit of *Venus* in 1874.

The arrangements respecting the time-gun, time and meteorological observations remain as before.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

There has been no change in the observational work of this Observatory since the last report. The measurement of double stars and the phenomena of *Jupiter's* satellites have received the largest share of attention. The weather of 1882 was exceptionally bad here, and the observations were much interrupted.

Mr. Huggins' Observatory, Upper Tulse Hill.

The following is a summary of the work of this Observatory during the past year:—

(*a*) On March 7 a photograph of the spectrum of the great nebula in *Orion* was obtained. The spectrum extends from a little below F to beyond M in the ultra-violet. The photographic plate shows a spectrum of bright lines, and also a narrower continuous spectrum probably due to stellar light. The bright stars forming the trapezium in the fish's mouth of the nebula were kept close to the side of the slit, so that the light from the adjacent brightest part of the nebula might pass to the plate. Outside this narrow continuous spectrum a very faint continuous spectrum is suspected. The photograph shows faintly but satisfactorily the four bright lines discovered in the nebula by Mr. Huggins in 1864, and beyond these known lines, in the ultra-violet a new line of great relative strength which has a wave-

length of about 3730. This line appears to correspond to ζ of the typical spectrum of the white stars obtained by Mr. Huggins.* Very faint lines are suspected in the spectrum between $H\gamma$ and λ 3730, and also, possibly, beyond λ 3730.

(b) On the evening of May 31, a photograph of the spectrum of Comet I. (Wells) was obtained, a comparison spectrum of *a Ursæ Majoris* being taken on the same plate.

The photograph shows a strong continuous spectrum extending from about F to a little beyond H. For the first time since spectrum analysis has been applied to the light of comets, the visible spectrum of this comet consisted principally of bright lines including those of sodium, the usual carbon bands being excessively faint. So also the photographic spectrum differs from that which Mr. Huggins obtained of the bright comet of 1881. The cyanogen group in the ultra-violet, and other lines probably due to carbon, are not to be seen in the photograph, but five brighter spaces between F and H probably indicate groups of bright lines. The positions of the brightest parts of these groups are—

λ 4764
4634
4507
4412
4253

(c) From the end of May till September 28 a series of photographs of the Sun was taken under conditions which it was expected would enable the corona to be obtained upon the plates. The slit photographs taken in Egypt on May 17 had shown that the corona light is very strong from about G to H. It appeared probable to Mr. Huggins that by cutting down the Sun's light to this part of the spectrum, and by the use of photography which is very sensitive to minute differences of illumination, those parts of the atmospheric glare which have the corona behind, might be sensibly stronger in the photographs than the parts of the atmospheric light where no coronal light is present.

The photographs were taken with a reflecting telescope by Short, 3½ feet focal length, arranged as a Newtonian, the aperture being reduced to 3 inches. The light was restricted to the small range of refrangibility of from about G to H, by means of screens of coloured glass, and also by a cell containing a strong solution of potassic permanganate. These screens were placed immediately in front of the sensitive surface. The gelatine plates were backed with asphaltum dissolved in benzole. Very different exposures were given. In about twenty plates an appearance peculiarly coronal is seen about the Sun. This does not consist merely of increased photographic action about the sun, but shows distinct forms which were found to accord well with those

* "Photographic Spectra of Stars," *Phil. Trans.* 1880, part ii. p. 669.

in the plates taken in Egypt. In the longer exposed plates the outer corona with its rays of varying length and peculiar rifts is seen; in the plates with a shorter exposure the inner corona, which is more nearly uniform in height, may be seen under suitable illumination. The average heights of the outer and inner coronæ agree closely with the coronæ as seen on the plates taken in Egypt.

On account of the great importance of these results, Mr. Huggins was desirous of having his own opinion confirmed as to the reality of the coronal forms on his plates. Professor Stokes and Captain Abney kindly examined them with much care, and have permitted him to say that in their opinion the corona has really been photographed without an eclipse.

The great Equatorial (belonging to the Royal Society) has been dismounted for improvements since June. It has, therefore, been impossible to continue photographic work on the spectra of the stars and nebulæ; and for the same reason no observations of the great comet of last autumn could be made.

The Earl of Rosse's Observatory, Birr Castle.

The year 1882 was more unfavourable than usual for astronomical work, observations having been made on forty nights only during the ten months in which the assistant was at his post. On 321 nights clouds were recorded at 9 p.m., and 335 nights were classed as more or less cloudy. Rain also is recorded to have fallen on 221 "days." The months of April and May, however, during which Dr. Boeddicker was absent in Germany would, if included, have somewhat increased the proportion of observing nights.

Three sketches of the planet *Mars* and six of *Jupiter* were made during the year with the 3-foot Reflector; also thirty-four sets for nebulæ were made with the 6-foot Reflector.

Some sketches of Comets *b* and *c*, 1881, and of the planet *Jupiter* in the season 1880–1, were published in the course of the year by the Royal Dublin Society; and a series of eighteen sketches of the planet *Mars* when last in opposition are in course of publication by that Society.

A series of sketches of the planet *Jupiter*, made during the season 1881–2, is in our portfolio.

Some lunar-heat determinations, made at intervals by Dr. Boeddicker are in process of reduction, and will probably be employed to confirm, or modify, as the case may be, the extinction and lunar-phase curves, as given by Dr. Copeland.

The Transit of *Venus* of December 6 was seen occasionally with the 3-foot between clouds, the enlarged image being projected upon a screen, but the Sun was invisible at the times of the contacts.

The meteorological observations have been made without interruption the same as last year.

A new polishing machine for 3-foot specula was constructed during the year. It is very similar in general mechanical arrangement to that sent out with the great Melbourne Reflector.* It has, however, been fitted for giving, in addition to the circular and straight strokes hitherto commonly employed, other motions with different relative times of rotation of the two excentrics as in Lassell's last machine.† The machine at its first trial, when the relative velocities of the excentrics were as 104 to 155 and their respective throws $\frac{1}{4}$ and $\frac{1}{3}$ the diameter of the speculum, gave a very good result, and it is hoped that subsequent experiences may be equally satisfactory.

Though it forms no part of the Observatory work, it may be mentioned that Dr. Boeddicker has during the year devoted a considerable amount of time to a discussion of the numerous papers which have from time to time appeared on the influence of magnetism upon the rates of chronometers. It is hoped that the paper, which is being published by the Royal Dublin Society, may be useful to succeeding workers on the subject.

Mr. Wilson's Observatory, Streete, Rathowen.

During the past year the mounting of the silver-on-glass Reflector of 2 ft. aperture by Grubb has been finished in the new Observatory. Observations have been made of the satellites of *Uranus* and *Saturn* and Comet *Wells*. The Transit of *Venus* was well observed in a cloudless sky. Six minutes after first contact the planet could be seen projected against corona, and surrounded by a ring of light. Internal contact $1^h\ 52^m\ 14^s$ S.M.T. No black drop. A series of observations in the infra-red end of the spectrum of different parts of the Sun's surface have been undertaken, and it is hoped that some of the results will be laid before the Society during the year.

* *Phil. Trans.* vol. clix.
† *Ibid.* vol. clxv.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Discovery of Minor Planets, 1882.

The following eleven minor planets were discovered in the year 1882:—

No.	Name of Planet.	Date of Discovery. 1882.	Discoverer.	Place of Discovery.
(221)		January 18	J. Palisa	Vienna
(222)		February 9	"	"
(223)		March 9	"	"
(224)		March 30	"	"
(225)		April 19	"	"
(226)		July 19	"	"
(227)	Philosophia	August 12	Paul Henry	Paris
(228)		August 19	J. Palisa	Vienna
(229)		August 22	"	"
(230)	Athamantis	September 3	De Ball	Bothkamp
(231)		September 10	J. Palisa	Vienna

The Supplement of the *Berliner Jahrbuch* still retains its distinctive character as the almost sole authority for the calculated ephemerides of the minor planets. In the Supplement recently received may be found daily ephemerides for the year 1883, for 43 members of the group, near the times of opposition, the places being given for midnight, Berlin time. There are also 20-day ephemerides giving less approximate places for noon for 112 planets throughout the year. The minor planets which appear to approach nearest the Earth in 1883 are *Isis*, *Phocea*, *Clio*, *Flora*, *Virginia*, *Polyhymnia*, *Fortuna*, *Metis*, and *Juno*, the least distances ranging between 0·895 for *Isis* and 1·180 for *Juno*, the radius of the Earth's orbit being unity.

E. D.

The Comets of 1882.

The number of comets that have actually been seen for the first time during the year is perhaps five, but of these only three have been continuously observed. The remaining two objects of a cometary character that have been reported, though interest-

ing of themselves, are, from various causes, not likely to find a permanent place in our catalogues. Each of these objects will be referred to in chronological order.

At the commencement of the year Comet VIII. 1881 (Swift) was the only comet visible, and observations were procured till the middle of January. As this comet was mentioned in the last Annual Report, no further notice of it is necessary here.

On March 17 a comet was discovered at Albany, U.S., by Mr. C. S. Wells, which was destined to attract considerable attention. At the time of its discovery it was small, bright, with distinct nucleus, and narrow tail. On March 19, from which date observations became frequent and continuous, Prof. Lewis Boss described the object as a great comet in miniature. The breadth of the head was about 30″, the length of the tail 6′ or 8′, and the nucleus shone with the light of a star of the eighth magnitude. An increase in brilliancy was steadily maintained, and early in May the comet was visible to the naked eye. Astronomers had been prepared for this increase of brilliancy, as well as for the subsequent display, by the determination of the orbit, which had been effected by several computers. Dr. Kreutz, from his first elements, predicted a theoretical brilliancy at the time of perihelion passage of nearly 6,000 times the brightness of the comet on March 20; and though subsequent discussion of the elements from improved data modified and somewhat diminished this value, no doubt remained of the interesting character of the orbit and the brilliant spectacle the comet was to present. The small altitude of the comet after sunset, and the bright background of the sky on which it was projected, interfered in some measure with its appearance, but the theoretical brilliancy was sufficiently great to warrant the conjecture that the comet would be visible in daylight. This actually proved to be the case. The comet was seen close to the Sun at many observatories. Possibly the smallest telescope with which it was so seen was the 6 ft. Refractor at Athens, where, on June 10, Dr. Schmidt saw the comet, 2°·8 distant from the Sun's limb. After perihelion passage, in July, the comet was seen, but with greatly diminished splendour, and observations were discontinued in August.

Many sets of elements have appeared; the most trustworthy orbit, though not definitive, is by M. Stefan Wolyncewicz. The perihelion distance is there given as 0·060768 that of the Earth's distance. Notwithstanding this close approach to the Sun, there is no difficulty in reconciling the observations previous to perihelion passage with those made subsequently, a point of some interest in connection with another comet discovered this year. When the observations made at the anomalies −160° and +152° are represented, a very satisfactory agreement is found to exist at intermediate points on the curve.

If the appearance of the comet owing to its unfavourable situation was disappointing, there are not wanting rigorous

observations to show that its brilliancy was even greater than might have been anticipated from the law of reflected light. Dr. Müller, of Potsdam, observing with a Zöllner Photometer, has determined that the light of the comet increased very rapidly, and that on June 6, when last seen, it possessed nearly forty times the brilliancy assigned by theory. Unfortunately, the small altitude of the comet necessitated the employment of a very serious correction, depending upon the extinction of light in the Earth's atmosphere. Dr. Müller has not given the data from which this correction has been taken, though, as he states that he has been engaged some years in investigating its amount, it is to be hoped that this doubtful element has been satisfactorily eliminated, and that Dr. Müller's interesting result will be entitled to implicit reliance.

The spectrum of this comet has increased the interest which its brilliancy awakened. Ever since 1864, when the spectrum of a comet was first observed by Donati, great uniformity has pervaded the spectra examined. All have shown the characteristic bands of hydrocarbon, but in this case, as soon as the comet had attained sufficient brilliancy for its spectrum to be observed, a marked deviation from the ordinary type was apparent; and inasmuch as the comet would approach very near the Sun, it was anticipated that some unexpected phenomena would be manifested. On April 7 the spectrum of the nucleus was seen to be continuous, though feeble and narrow, in which three ill-defined brighter points, corresponding approximately to the carbon bands, were just perceptible. By the 21st the difference between this spectrum and the ordinary type was so strongly marked, that the cometary nature of the object would hardly have been recognised. At the end of May the bright sodium line in the nucleus and neighbouring regions was detected at Dunecht. In the early part of June, when the comet attained its greatest brilliancy, this line under adequate dispersion was seen to be double, and the behaviour of the more refrangible line indicated to Prof. Vogel that the density of the incandescent gas was very great. A want of exact coincidence between the bright sodium lines and the Fraunhofer lines was noticeable on June 6, when the comet had a motion in the line of sight of 3·7 miles per second. The more refrangible portion of the spectrum was photographed by Dr. Huggins after an exposure of the plate for seventy-five minutes, and showed that the essential difference observed in the visible spectrum was maintained at the more refrangible end. On the plate was seen a strong continuous spectrum extending from F to a little beyond H, without any Fraunhofer lines, from which Dr. Huggins concludes that the part of the comet's original light which gives a continuous spectrum, is much stronger relative to the reflected solar light than was the case with the comet last year. The groups in the ultra-violet, presumably due to cyanogen, were not present. In the continuous spectrum five places of greater

brightness were evident, possibly owing to the sodium detected in the visible spectrum.

On May 17, during the total eclipse of the Sun at Sohag, a comet was seen and photographed on the plates prepared to receive the picture of the corona. The comet was distant from the Sun about a solar diameter, and had a tail of half a degree in length. It was never seen again. This observation, possibly unique, recalls, however, the obscure but interesting account of the comet of 418, quoted by Pingré in his *Cométographie*.

On Sept. 13, Mr. Barnard, of Nashville, Tennessee, discovered a faint telescopic comet. Never attaining any great brilliancy, and moving rapidly southwards, it failed to attract much interest. It remained in view of northern Observatories some weeks, passed through its perihelion on Nov. 12, and has been observed since at the Cape of Good Hope, so that ample materials exist for the determination of the orbit, which is probably parabolic.

The Great Comet.—Information of the discovery of this comet first reached Europe on Sept. 12, by a telegram from M. Cruls, of Rio Janeiro; but in the southern hemisphere the comet had been seen as early as the 3rd, and observations had been made by Mr. Tebbutt and Mr. Finlay on the 8th. The announcement of the appearance of another comet, visible to the naked eye, the fourth which had been seen in twelve months, was however of inferior interest to the intelligence of the independent discovery of the same comet by Mr. Common, who, following a plan of observation which he had for some time pursued, detected it near the Sun's limb on the morning of Sept. 17. Mr. Common's observation showed that the comet was approaching the Sun at the time, but owing to clouds the object appears to have been lost sight of a little after noon. The interesting phenomenon therefore of the approach of the comet to the Sun's limb, and the actual transit over the Sun's disk, was missed; but more favourable weather at the Cape of Good Hope permitted Mr. Finlay and Dr. Elkin to make this unique observation. The comet was traced right up to the limb of the Sun, where it disappeared as suddenly and as effectually as the occultation of a star by the Moon. The distance of the comet from the Earth was [9·99191], the radius vector of the Sun [0·00192], so that it passed between us and the Sun, but the observers did not know at the time whether the comet was transiting the Sun or whether it was occulted by it, so completely had every trace of the nucleus, which was $5''$ in diameter, vanished. Similar observations to those recorded by Pastorff and Stark, and which have been thought to refer to the transit of comets over the Sun, would seem therefore to need a different explanation.

The elements of the orbit when they appeared disclosed an unexpected feature—namely, their close agreement with those of the comets of 1843 and 1880, a coincidence that has given rise to various hypotheses, specious and startling. The identity of

the comet of 1843 with that of 1880 had been rather reluctantly admitted, since the classical investigation of Hubbard had shown that the earlier comet was moving in an orbit of 533 years, and it had been first necessary to prove that the observations of 1843 could be represented by an orbit of about 37 years. This attempt was only partially successful. If a period of 37 years is to be substituted for that which is rigorously deduced from the observations, it necessitates an increment of —·000498484 to the excentricity, and corresponding corrections to the other elements. Since Prof. Hubbard has calculated the effect on the elements of an arbitrary change in the excentricity, these corrections can be immediately introduced. This alteration in Hubbard's elements has been effected by Prof. Weiss, who has shown that when the observations are compared with the theoretical places derived from the new elements, the probable error of a single observation is increased from 8″·4, the value found by Hubbard, to 39″·4. If fresh elements be sought, which is desirable, since the coefficients of the variations of the elements are only applicable so long as the functions can be considered linear, the residual errors, though considerably reduced, remain conspicuously greater than those found by Hubbard, as shown in the table below.

Date. 1843.	Independent Orbit. $\Delta\alpha$	$\Delta\delta$	Deduced Orbit. $\Delta\alpha$	$\Delta\delta$	Hubbard's Orbit. $\Delta\alpha$	$\Delta\delta$
	″	″	″	″	″	′
Mar. 5	+ 7·0	+ 18·4	− 117·9	+ 73·2	+ 25·7	+ 12·9
25	+ 19·4	− 48·6	+ 39·5	− 12·9	+ 4·6	+ 5·5
Apr. 19	− 14·5	+ 35·1	− 54·3	+ 61·1	− 8·7	+ 9·3

This want of agreement was, however, explained away by supposing that the centre of gravity did not correspond with the centre of condensation, and that an argument drawn from the comparative smallness of the residuals was not final.

There was but little difficulty in representing the observations of the 1880 comet by an ellipse of 37 years' period, but in this Dr. Meyer, of Geneva, was greatly assisted by the small length of the comet's heliocentric path—viz. three degrees. He has decided that the observations can only be satisfied with an ellipse whose period lies between the limits 31·5 and 47·7 years, but this conclusion is arrived at simply by considering the effects of the variation of the excentricity on the other elements. No attempt has been made to represent the observations by an ellipse of 533 years, the other elements of the orbit being independently derived, though the necessity of so doing was proved by Prof. Weiss in the previous case.

But after it had been decided to accept the period given by the supposition of the identity of the two bodies, rather than that derived from the discussion of the 1843 observations, which were scattered over an arc of only eight degrees of true anomaly, it was inconvenient and perplexing to find another magnificent

comet moving in the same track, after an interval of only $2\frac{1}{2}$ years. To account for this phenomenon, a theory, to which the name of Prof. Klinkerfues is particularly attached, was resuscitated and obtained some favour. This astronomer had supposed that the comets of 1880, 1843, 1668, and B.C. 371 were each apparitions of the same object, whose orbit was being gradually curtailed by successive passages through the "resisting medium." It was contended that if one-thirteen hundredth part of its initial velocity was destroyed by the resistance of the solar vapour, the contraction of the orbit would be such as to approximately coincide with the appearances observed, and that the next return might be anticipated in 1897. A reappearance in 1882 was of course premature, and necessitated a still further reduction of the axis major, yet as there was some difficulty in reconciling the observations made before perihelion with those made immediately after, and as this difficulty could be easily removed or explained by supposing some resistance to have been offered to the comet when in the neighbourhood of the Sun, this hypothesis did obtain for a time some sanction. Continued observations have, however, to some extent removed this apparent disagreement between the observations made on the two arcs of the ellipse, and have conclusively proved that no very short period will satisfy the observations. On the other hand, no parabola nor very extended ellipse will represent the observed path. Definitive elements are not yet known; but the best orbits yet published give such periods as 794, 843, or $652\frac{1}{2}$ years, indicating axes major not greatly different from that found by Hubbard.

An alternative theory which was suggested in 1880 obtains now a more general support—namely, that the three comets have had in the past a common origin, but by a process of gradual disintegration, the original mass has detached fragments which, pursuing slightly different paths, arrive at their perihelia at irregular intervals. The bifurcated orbit of the dichotomised comet of Biela furnishes an example of the diverging paths, along which portions of the same comet may move, becoming gradually separated in space.

The gradual dissolution of the comet itself, suggested by the latter theory, receives some support from the behaviour of the comet while under observation. Not only has the inconstant form of the nucleus been so pronounced as to introduce additional difficulties in the determination of the orbit, but Dr. Schmidt has observed (Oct. 9) a nebulous object in the neighbourhood of the comet, which there is some reason to believe is a detached fragment of it. This nebulous body was seen only on three consecutive mornings at a very low altitude, and with condensations so ill defined that the observations were only approximate. The consequent determination of the orbit is therefore very insecure. The elements, however, that have been derived do show some similarity, particularly in the small perihelion distance, with those of the great comet, and suggest

strongly the idea of a past intimate connection. But the final settlement of the entire question must await the complete discussion of the observations now in progress.

The appearance of the comet, the structure of the tail, the formation of the head, &c., have been graphically described by many observers in current scientific periodicals of easy access; and photographs taken at the Cape and elsewhere have preserved the general features. The spectrum has been the subject of special study, and has indicated some fresh facts of interest. It is curious to notice, that while the spectrum of comet *Wells* was continuously observed as the comet approached the Sun, and illustrated the effects of great and increasing excitement, the spectrum of this comet could only be observed as it receded from perihelion, and consequently the phenomena that were observed in the preceding case might be expected to exhibit themselves here in a reversed order. This, to a great extent, actually occurred. When the spectrum was first seen on Sept. 18, the sodium lines were at once seen distinctly double, both in the nucleus and parts adjacent, while a number of other bright lines coinciding with the more prominent iron lines were visible. Of the ordinary banded spectrum there was no trace. On Sept. 29 the iron lines had quite disappeared, the D lines were not separable, and indications of the ordinary comet spectra were apparent, while at the end of October, when the comet had reached the Earth's distance from the Sun, all trace of the sodium lines had vanished, and the three bands of hydrocarbon were distinctly present. It has been suggested by Dr. Hasselberg and others that the entire explanation of the phenomena witnessed cannot be found in the simple increase or diminution of temperature, depending on the distance of the comet from the Sun. For though an increase of temperature might account for the appearance of metallic lines, it does not satisfactorily explain the simultaneous disappearance of the characteristic carbon bands. The entire solution, it is submitted, is to be found by supposing that the cometary light is to some extent due to electric discharges, a supposition the more tenable, since laboratory experiments conducted on hydrocarbons and sodium vapour, have shown how preferential is the electric discharge when both these vapours are present.

W. E. P.

The Comet of 1812.

For this comet Encke had computed an orbit of about 70 years period, and consequently the return of the comet might have been expected very shortly. It was therefore desirable, as the time approached, to have a more rigorous investigation, in order to predict the date of its return within narrower limits, and supply the means for a systematic search for its discovery.

This task MM. Schulhof and Bossert have undertaken, and carried to a successful issue, with a care and elaboration that astronomers will appreciate. The observations have been re-reduced in order to introduce the best places of stars of comparison, and correct values of astronomical constants. In those series of observations in which systematic errors were suspected, special precautions have been taken to eliminate their effects from the final result. The solution of the equations of condition has been so effected that each of the derived corrections to the elements is accompanied with a term depending upon the correction to the excentricity. If this correction be made =0 the most probable period is 73·18 years, but as the excentricity correction may vary between the limits ±0·0018 the uncertainty in the period unfortunately amounts to 4·5 years. According to three possible combinations in which the observations may be grouped, the authors derive periods of 73·23, 73·19, and 75·01 years, and the conclusion is that the period is probably longer than 73·18 years. The effect of perturbation of the four superior planets has been calculated up to May, 1884. The return of the comet is thereby accelerated 445 days, and MM. Schulhof and Bossert have fixed Sept. 3, 1884 for the date of the next perihelion passage. As in 1812 the date of the perihelion was Sept. 15, the path in the heavens would nearly coincide with that of 1812, and the chances of its detection would be correspondingly great. If, however, the nearest approach to the Sun occurs between March and July, the chances of reobservation are slender.

Prof. Kirkwood had called attention to the possible intimate connection between this comet and that of De Vico of long period, since, with the exception of the longitude of the ascending node, there was a general similarity in the elements of the two orbits. This suggestion is favourably received, and it is further pointed out that each comet approaches closely to the orbit of *Venus* at about the same true anomaly.

Comet 1812.	True anomaly $341^{\circ}\cdot2$.	Distance from *Venus'* orbit	0·076.
„ 1846 IV.	„ 347·1.	„ „	0·049.

Most extensive ephemerides are furnished by combining the values of true anomaly with different values of the solar co-ordinates, and which, while they point out the more likely positions in which the comet may be sought, decide at once whether any comet accidentally discovered is that whose return is expected. This latter portion of the work had been to some extent anticipated by Dr. Winnecke, who published, in 1877, a system of sweeping ephemerides, based, however, upon the less rigorously deduced elements of Encke.

W. E. P.

The Transit of Venus, 1882.

Three different methods have been applied to obtain a determination of the Sun's distance from observations of the transit of *Venus* in 1882, December 6.

The British have relied chiefly on the method of contacts; the Americans chiefly on the photographic method; the Germans on direct Heliometer measures; whilst the French have combined the method of contacts with some attempts at photography. Two Belgian expeditions have been sent out, one under M. Houzeau for Texas, the other under M. Niesten for Chili, furnished with heliometers of a novel construction devised by M. Houzeau; but no information of the success of these expeditions has hitherto reached us.

It would appear that sufficient observations have been obtained to give each method a fair trial.

The British arrangements were rendered more complete than would otherwise have been the case from the existence of Observatories at the Cape of Good Hope, Mauritius, Sydney, Adelaide, and Melbourne, in the south; and the assistance rendered by the Canadian Government in the north.

The readiness and liberality shown by the Governments of the different Colonies to assist the work have rendered the operations much more complete than could otherwise have been the case. The devotion of funds to such an object is a proof of the intellectual, as well as of the material, prosperity of our Colonies and of their kindly feelings towards the old country.

The following is a list of the stations occupied by the British, with the names of observers.

Retarded Ingress and Accelerated Egress.

The following three stations were occupied by observers from England, and the contacts were observed both at Ingress and Egress at all three stations:—

Stations.		Observers.
Bermuda	... ...	Mr. J. I. Plummer, of Orwell Park Observatory. Ipswich; Lieut. Neate, R.N.
Jamaica	... ...	Dr. Copeland, of Dun Echt Observatory, Aberdeen; Capt. Mackinlay, R.A., and Dr. Pearson, of Emanuel College, Cambridge. Mr. Hall not yet reported.
Barbadoes	... ...	Mr. Talmage, of Leyton Observatory, Essex, and Lieut. Thomson, R.A.

The following stations were equipped by the Canadian Govern-

ment. The instruments used were from four to six inches aperture:—

Stations.	Observers.
Winnipeg	Prof. McLeod. 2 contacts observed.
Woodstock	Prof. Wolveston.
Toronto	Mr. Carpmael, Superintendent.
Kingston	Prof. Williamson. 3 contacts observed.
Whitby...	Prof. Hare.
Cobourg	Prof. Bain. 1 contact observed.
Belleville	Mr. Shearman.
Ottawa...	T. L. Blake, Esq., Dominion Land Surveyor. 4 contacts observed.
Montreal	Prof. Johnson.
Quebec...	Dominion Observatory, Lieut. Gordon, R.N.
Halifax	Mr. A. Allison.
Fredericton	Prof. Bryden Jack.

The observers were all trained by Lieutenant Gordon, who visited Oxford for the purpose of making himself acquainted with the kind of contact to which attention was chiefly directed. The instruments were all good 4- and 6-inch telescopes, and powers of from 120 to 150 were used. Time-signals were interchanged between all the stations and the observatories of Toronto and Quebec. Although the observations have been unfortunately lost at many of the stations, those secured will be of the greatest value.

Some few observations have been obtained in the British Isles, and at Rome, Munich, and Lisbon; but the weather was generally unfavourable throughout Europe.

Accelerated Ingress.

Stations.	Observers.
The Cape Observatory .	Mr. Gill, H.M. Astronomer, and Staff.
Aberdeen Road ...	Mr. Finlay, B.A., First Assistant of the Cape Observatory; Mr. Pett, Third Assistant.
Montagu Road ...	Mr. Marth, F.R.A.S., and Mr. C. M. Stevens.
Natal	Mr. Neison, F.R.A.S.
Madagascar	Rev. S. J. Perry, Rev. W. Sidgreaves, Comm. Aldrich, H.M.S. "Fawn," Mr. Carlisle.

Three contacts were observed at this station.

Stations.	Observers.
Mauritius	Mr. Meldrum (contacts at Ingress well observed).

RETARDED EGRESS.

The details have not yet been received from the different stations, but in New Zealand the observers—Col. Tupman, R.M.A., and Lieut. Coke, R.N.—have successfully observed the contacts, as well as several Colonial observers, provided with adequate instrumental means.

Melbourne.—Mr. Ellery and staff have been successful in observing the contacts and in securing some photographs.

Adelaide.—Mr. Todd reports that he has obtained an exceedingly good internal contact from a station at some little distance from Adelaide.

Brisbane.—Observations near this station were prevented by clouds. The loss of these observations is greatly to be regretted, as there were three observers at the station: Capt. Morris, R.E., Lieut. Darwin, R.E., and Mr. Peek, who had provided himself with an equipment and joined this party at his own expense.

Sydney.—Mr. Russell and his staff had made elaborate arrangements for observing the transit, but clouds prevented anything being done at these stations.

Capt. Wharton, of H.M.S. "Sylvia," has observed near Sandy Point, Straits of Magellan, both the Ingress and Egress. These observations afford a fair difference of duration as compared with the northern observations, and will be valuable as a check upon the Ingress and Egress observations, because but little affected by error in the adopted value of the parallax.

The method of contact, like every other method, has its difficulties; but these appear to be dependent solely on the possibility of three kinds of contact being mistaken for each other. There is an appearance of light breaking through at the point of contact when the atmosphere of the planet *Venus*, or the penumbra, first comes upon the Sun's disk. This is sometimes called geometrical contact, or "first appearance of light," and in case of broken weather or clouds there would be great danger of the observer taking this for the "contact" as defined by the last appearance of any well-marked and persistent disturbance of the illumination of the Sun's limb near the point of contact, or the first appearance of direct sunlight. There is also seen after this "contact," in cases where the sky is exceedingly clear and the attention of the observer is *directed* to the point, some slight flickering, shadowy disturbance which gradually fades away, but is of so faint and undistinguishable a character that it could never by any observer be mistaken for the "contact" phase; but, although this is the case, unless care be taken in describing the phenomena seen, persons who have never themselves seen a transit of *Venus* might well be mistaken as to the observer's meaning, and might possibly be inclined to consider such observations as referring to the "contacts." These possible kinds of contact are, however, so widely separated

that no real difficulty should be encountered in referring the observation to the proper phase.

The American expedition to the Cape has been completely successful in securing the required observations; and it is understood that the expedition to Tasmania has also been successful. The weather generally in the northern States of America appears to have been of a broken character: but sufficient photographs have been obtained to afford a fair trial of the photographic method.

The following are the French stations:—

MISSION DE PORT-AU-PRINCE.

MM. D'Abbadie, Membre de l'Institut;
Chapuis, Lieutenant de vaisseau;
Callandreau, Aide-astronome à l'Observatoire de Paris.

MISSION DU MEXIQUE.

MM. Bouquet de la Grye, Ingénieur hydrographe de la Marine;
Héraud, Ingénieur hydrographe de la Marine;
Arago, Lieutenant de vaisseau.

MISSION DE LA MARTINIQUE.

MM. Tisserand, Membre de l'Institut;
Bigourdon, Aide-astronome à l'Observatoire de Paris;
Puiseux, „ „ „

MISSION DE LA FLORIDE.

MM. le Colonel Perrier, Membre de l'Institut;
le Commandant Bassot;
le Capitaine Defforges;
Tourenne, Photographe.

MISSION DE SANTA-CRUZ.

MM. Fleuriais, Capitaine de frégate;
Le Pord, Lieutenant de vaisseau;
De Royer de Saint-Julien, Lieutenant de vaisseau;
Lebrun, Naturaliste.

MISSION DU CHILI.

MM. de Bernardières, Lieutenant de vaisseau;
Barnaud, Lieutenant de vaisseau;
Favreau, Enseigne de vaisseau.

MISSION DU CHUBUT.

MM. Hatt, Ingénieur hydrographe de la Marine;
Mion, Sous-ingénieur hydrographe de la Marine;
Leygue, Lieutenant de vaisseau.

MISSION DU RIO-NEGRO.

MM. Perrotin, Directeur de l'Observatoire de Nice;
Delacroix, Lieutenant de vaisseau;
Tessier, „ „
Guénaire, Photographe.

The German expeditions have all been placed on the American continent. They have all been partially successful in observing the contacts; but sufficient heliometer measures have, it is understood, been obtained to give this method also a fair trial.

The longitude determinations made in connection with the Transit of *Venus*, 1882, will, of course, have a value quite independent of the use made of them in the reduction of the observations of the transit. The principal determinations are—the connection of the New Zealand and Australian stations *inter se*, and through Port Darwin, Singapore, and Madras with Greenwich; the connection of Madagascar through the Cape Observatory with Greenwich; the connection of the South African stations with the Cape Observatory; and the connection of Bermuda through New York with Greenwich. The telegraph lines have in all cases been placed at the disposal of the observers for carrying out the work. The thanks of astronomers are due to the different governments, companies, managers, and telegraphists for the assistance afforded.

In all cases where the position of *Venus* has to be referred by measures to the Sun's centre there are of course difficulties presented, when working to the small quantities with which we are now concerned in these inquiries, by the necessity for refraction corrections and possible systematic errors of scale value under the circumstances of observation and by unequal contraction or distortion of photographic films, and the successful elimination of such errors from the results can hardly be asserted except from the agreement between the measures obtained at different stations.

It will, of course, be some time before the different results can be laid before us; but their publication will be received with the greatest interest. Our successors can hardly charge us, at least, with having made no serious effort to utilise the opportunity presented to us by the occurrence in our day of a transit of *Venus*. E. J. S.

M. Gogou on a Lunar Inequality of Long Period due to the Action of Mars.

In Vol. xxxviii. of the *Monthly Notices*, Mr. Neison announced the existence of an inequality of long period in the mean longitude of the Moon due to the action of *Mars*, the coefficient of which amounted to $7''\cdot55$, the period being 406 years. In an elaborate paper presented to the Faculty of Sciences of Paris in order to take the degree of Doctor in Mathematical Science, M. Gogou has investigated this inequality anew, taking into account many terms which had been neglected by Mr. Neison. He shows that even in the first approximation it is not sufficient to regard the elements of the Moon's orbit as constant when taking into account the disturbing action of *Mars*, but that it is necessary likewise to consider the modification of this disturbing action produced by variations in the lunar elements due to the perturbing action of the Sun. He also takes into account the inclination of the orbit of *Mars* to the ecliptic.

In this investigation M. Gogou follows the method laid down in Delaunay's Lunar Theory, a method of which he shows a complete mastery. The calculations are necessarily very long, but they appear to have been most carefully made. M. Gogou has had to calculate the quantities ordinarily denoted by $b^i_{\frac{1}{2}}$, $b^i_{\frac{3}{2}}$, $b^i_{\frac{5}{2}}$, and $b^i_{\frac{7}{2}}$, and their differential coefficients for values of the index i extending from 18 to 25.

For such high values of the index, the method of deriving the quantities b^i successively from the first two of them, b^0 and b^1, would have led to most inaccurate results.

The definitive result at which M. Gogou arrives is that the coefficient of the inequality of the Moon's mean longitude now in question only amounts to

$$0''\cdot00034,$$

a quantity which is, of course, absolutely insensible.

It is difficult to see how the enormous difference between this result and Mr. Neison's originates.

M. Gogou has shown that it does not arise from the omission of the terms neglected by Mr. Neison. It may be mentioned that Professor Adams has minutely verified several of M. Gogou's values of the quantities b^i, and their differential coefficients.

Oppolzer's "Syzygien-Tafeln."

These tables, which form Publication XVI. of the Astronomische Gesellschaft, are intended to supply a simple and convenient means of finding very approximately the time of

New or Full Moon, particularly in the case of an ecliptic syzygy, and of calculating all the circumstances of an eclipse, without the necessity of having recourse to the Solar and Lunar Tables.

The form of the tables is adapted to the method of calculation employed in Hansen's Theory of Eclipses.

Compendious ecliptical tables intended to answer the same purpose were published by Hansen himself in the *Berichte der Sächsischen Gesellschaft* for 1857, and in the same publication for 1863 he gave the analysis on which the tables were founded. Nearly the same method has been employed in the formation of the present tables, but the approximation is carried further, and the results are given with much greater fulness of detail. The periodic quantities tabulated depend on eight arguments only, but in the formulæ given in the Introduction, the values of many more small terms are added.

Complete formulæ for the calculation of eclipses by means of the tables are given, as well as examples of their application.

In an Appendix, M. Oppolzer compares the circumstances of many of the eclipses recorded in ancient history with the results of his ecliptical tables. One of the tables contains the empirical corrections which he finds it necessary to apply to the arguments at remote epochs, in order to produce a better agreement between the calculated and the observed results.

The Harvard College Observatory Catalogue of Stars for 1875.

This important Catalogue, which is published in vol. xii. of the *Annals*, has lately been carefully discussed in the *Memoirs* of the American Academy, vol. x., by Prof. Rogers, who had made the observations of the stars, superintended their reduction, and determined their proper motions.

The comparison of this Catalogue with others is interesting, inasmuch as the method of observation differed in some respects from that in common use. Spider-lines were replaced by lines on glass, in order to avoid possible errors due to their weight and to the effect of moisture. Stars were then observed between double lines instead of when bisected by single threads, and declinations were determined by transits over oblique lines; the especial advantage of the last method being that the instrument is not touched during the observation.

This Catalogue is constructed from observations extending from April 1871 to May 1872, published in vol. x. of the *Annals*, combined with two series of observations made during the years 1874 and 1875. The observations of 1871 and 1872 depend upon the places of the provisional Catalogue of 539 stars published in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, 1869, which consists of 336 principal stars whose positions were at that time

known within narrow limits, and of 203 secondary stars whose places were known with less precision. The observations of 1874 and 1875 depend upon the Pulkowa Catalogue of Zusatzsterne, published by Professor Struve in 1874. In his discussion of the Catalogue Prof. Rogers shows that the systematic deviation of these Pulkowa observations from the final positions of the several stars given by Auwers in his Fundamental Catalogue (*Publication der Astronomischen Gesellschaft*, xiv.) is quite large, especially in declination. In so far, therefore, as these stars were used in the determination of the instrumental constants for the years 1874 and 1875, there is a departure from the system upon which the 1872 observations are based.

The Primary Catalogue consists of 334 stars, and the Secondary Catalogue of 284 stars, the positions being derived from the mean of the three places for 1871–2, 1874, and 1875. giving to each a weight proportional to the number of observations, and giving one-half weight to the lower culminations, In the Primary Catalogue the annual variations have been computed with Bessel's constants, and include the provisional values of the proper motion given in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, vol. iv.

In the Secondary Catalogue the provisional values of the proper motion given in vol x. of the *Annals* are employed. These values rest upon the assumption that if the positions given by different authorities at various epochs are reduced to a homogeneous system, the systematic error belonging to each authority will not appear in the resulting proper motion.

In his very able memoir on "A Comparison of the Harvard College Observatory Catalogue of Stars for 1875·0 with the Fundamental Systems of Auwers, Safford, Boss, and Newcomb," Professor Rogers remarks that it is obvious that in the reduction of a given series of observations from the system of one fundamental catalogue to that of another system, the most independent method of procedure would be to apply to the given series the systematic corrections derived from comparing the system upon which it is based with that to which it is to be reduced. The fact that the Harvard College Catalogue for 1875 depends upon two systems which differ systematically makes it imperative that the comparison shall be made directly with Auwers. He has accordingly given in his memoir the Catalogues of primary and secondary stars reduced to the fundamental system of Auwers; to which are appended the differences between the Harvard College Catalogue and Auwers, Safford, Boss, and Newcomb, the last three Catalogues being reduced to the system of Auwers.

The result of the comparison is to show that the Harvard College observations are of a very high order of excellence, reflecting great credit upon Professor Rogers, who had made them.

Double Star Observations.

The energy displayed by observers of late years in this interesting branch of astronomy has in no way abated, and some important contributions have recently appeared.

Mr. S. W. Burnham, whose work in this direction is not only so extensive but also of such high excellence, has recently communicated to the Society a valuable series of Double Star Observations, made in 1879 and 1880 with the 18½-in. Refractor of the Dearborn Observatory, Chicago, which will appear in the *Memoirs*.

Since 1875 the Cincinnati Observatory has been steadily devoted to the micrometric measurement of double stars. The first publication issued by Professor Ormond Stone, the Director, contained a catalogue of 50 new double stars discovered at that Observatory, and which has been already noticed by the Council. The following issue was devoted to the publication of the Double Star Observations made by Professor O. M. Mitchel at the old Observatory at Cincinnati, in the years 1846 to 1848. This series is important, as, with the exception of the observations of Dawes and Mädler, very little micrometric work on double stars appears to have been undertaken at any observatory during this period. In 1875 Professor Ormond Stone decided to devote the 11-in. Refractor of the Observatory to observations of double stars between 15° and 35° of South Declination—a region where our knowledge of double stars depended almost entirely upon the observations of Dunlop, Sir John Herschel, Jacob, and Powell, of which a large portion of Sir John Herschel's stars had never been micrometrically measured. The original object of the observations was subsequently modified to the preparation of a general catalogue of known double stars situated between the equator and 30° South Declination.

The observations up to 1880, September 1, contained in Numbers 3 to 6 of the Publications of the Observatory, consist of the following results:—

No. 3.	371	Observations of	166	Double Stars.
4.	930	,,	517	,,
5.	2250	,,	1054	,,
6.	750	,,	455	,,

The above observations are, however, not confined to southern stars, but include several objects which Mr. Burnham had indicated as needing re-observation, besides some other northern stars.

Northern stars have been usually observed once, and southern stars twice, in position-angle and distance.

The work has been steadily pursued by Professor Ormond Stone, and the results cannot fail to be of value.

Mr. Russell, of the Sydney Observatory, has presented to the Society a paper, which will appear in the *Memoirs*, containing a micrometric revision of Sir John Herschel's Southern Double Stars, and which will form an interesting comparison with the Cincinnati Observations.

Professor Schiaparelli has recently published in the *Rendiconti del R. Istituto Lombardo* a valuable series of measurements of 32 known binary stars having rapid orbital motion. These were made with the Merz 8½-in. Refractor of the Brera Observatory at Milan, in the years 1875–1882. The total number of observations is 967, and they have evidently been made with the greatest care, and bear favourable comparison with the best micrometric measurements in existence. The comparison with Dembowski, for example, yields the following result:—

	S.—D.		
Distance.	Position-angle.	Distance.	No. of Stars.
″ ″	°	″	
0—1	−0°·55	−0″·023	16
1—2	−0·44	+0·035	14
2—4	−0·10	+0·052	21
4 and above	−0·04	−0·026	12

Professor Schiaparelli's results will form important data in the discussion of the orbits.

The Leipzig Observatory has only lately published some observations of 162 double stars made with the Equatorial by Dr. R. Engelmann in the years 1864–1867. The details of the observations are given, and the comparison with good observations at the same epoch shows a satisfactory agreement.

In vol. i. of the Publications of the Washburn Observatory, Wisconsin, the Director, Professor Edward S. Holden, has published a list of 60 new double stars discovered mostly by himself in the zone observations at that Observatory, from April 23 to September 30, 1881, and which have been micrometrically measured by Mr. S. W. Burnham. The stars vary in distance from 0″·6 to 7″, and the measurements average about three determinations of position-angle and distance for each star. Following this catalogue is a list of 88 new double stars discovered and micrometrically measured at the Washburn Observatory in the same period by Mr. Burnham; making 148 new double stars discovered at one Observatory in five months. This speaks for itself for the activity and energy of the Director, Professor Holden, and his able assistant, Mr. Burnham. In the same volume is published a series of measures by Mr. Burnham of about 150 double stars selected from his MS. General Catalogue of Double Stars, as specially needing observation. In these observations Professor Holden states that two observers participated, thereby saving much of the time usually

consumed in moving the dome and observing chair, setting the instrument, reading the circles and chronometer, recording the observations, and taking the means of the separate settings. By these means he states that from 25 to 30 stars can be completely observed in one night. The whole of the measurements in the above three lists appear to have been made in the period from April to September, 1881. Professor Holden deserves congratulation for the large amount of work on double stars of an evident high character produced at his Observatory in so short a time.

The Micrometric Measurements of the Harvard College Observatory.

A large quantity of micrometric work having accumulated at the Harvard College Observatory during the period 1866 to 1881, these have been reduced and published in vol. xiii. of the *Annals*. The observations are of a miscellaneous character: 1. A good series of double star measures made with a filar micrometer, mostly under the direction of Professor Winlock. This comprises a list of 172 new double-stars with approximate elements; and micrometric measurements of nearly 350 known double stars.

2. Micrometric, spectroscopic, and general observations of about 280 nebulæ—the positions of several being determined by measurements from known stars.

3. Micrometric observations of the satellites of *Saturn*, *Uranus*, and *Neptune*, made by Professor Winlock in the years 1866–1868. This series does not contain any observation of *Hyperion*, *Mimas*, *Ariel*, or *Umbriel*.

4. A very extensive series of observations of the satellites of *Mars* in 1877 and 1879 made under the direction of Professor Pickering.

In 1877 the measurements were made with a filar micrometer on the 15-in. Equatorial, reducing the light of *Mars* by covering a portion of the field with coloured glass and placing the planet behind its edge. The results for 1877 have been already published in the *Astronomische Nachrichten*. In 1879 a large series of observations of the satellites was obtained, comprising for position-angle, 75 measurements of *Phobos*, and 207 of *Deimos*, and for distance, 53 measurements of *Deimos*—no observation of the distance of *Phobos* being recorded. The observations are very fully discussed, and a good accordance is established between the two series made in 1877 and 1879, though different micrometer screws were used in each year.

5. Observations of asteroids with micrometrical measurements from comparison stars.

6. Observations of comets and comparison stars.

7. Occultation of stars and planets.

Researches on Stellar Parallax.

Professor Asaph Hall has recently published a determination of the parallax of *α Lyræ* from observations made by himself with the 26-inch refractor of the Naval Observatory. The observations were made on seventy-seven nights between May 24, 1880, and July 2, 1881. The method adopted was to observe simply the difference of declination of *α Lyræ* and its companion of the tenth magnitude. In the observations two kinds of illumination of the wires of the filar micrometer were used: A, dark wires with a bright field, and B, bright wires. The resulting values of the parallax for each method are

$$\text{A.}\quad \pi = 0''\!.1556 \pm 0''\!.00764$$
$$\text{B.}\quad \pi = 0.2080 \pm 0.00827.$$

Taking the mean by weight of these values, the final result gives

$$\pi = 0''\!.1797 \pm 0''\!.005612.$$

The time required for light to pass from this star to our Sun is 18·11 Julian years.

Professor Hall has also determined the parallax of 61 *Cygni* from observations on sixty-six nights, from October 24, 1880, to December 7, 1881, dark wires in a bright field being employed, from which the following result is obtained:

$$\pi = 0''\!.4783 \pm 0''\!.01381.$$

The time required for light to pass from this star to our Sun is 6·803 Julian years.

Professor Robert S. Ball, the Astronomer Royal for Ireland, in his search for stars with appreciable parallax, selected for observation 6 *Cygni*, a well known double star with large proper motion, the star B of the pair being employed for the investigation. A systematic series of measurements of the distance of a small 10·5 magnitude star was made from October 3, 1880, to December 22, 1881. The measures were made in a dark field with bright wires, and the following determination of the parallax is obtained:

$$\pi = +0''\!.482 \pm 0''\!.054.$$

Professor Ball considers this result as merely provisional; but he thinks it can hardly be doubted that a parallax of very considerable amount really exists. He further remarks that it is impossible not to be reminded of 61 *Cygni*, which is in the

same constellation, and the parallax of which is about the same amount. Both doubles are of the same general character, and have each a large proper motion.

Dr. O. Backlund has investigated some observations for determining the parallax of the star *Bradley* 3077, made by M. Wagner with the Transit Instrument of the Pulkowa Observatory. The method adopted was the determination of differences of Right Ascension between it and neighbouring stars. The observations were, however, made under rather unfavourable circumstances for the determination of parallax. The resulting parallax obtained from comparison with one star is

$$\pi = +0''{\cdot}20 \quad \pm 0''{\cdot}080,$$

and from comparisons with another star

$$\pi = +0''{\cdot}21 \quad \pm 0''{\cdot}078.$$

These values of π agree, within the limits of probable errors, with the value deduced by Gyldén, from observations made with the Equatorial of the Stockholm Observatory.

$$\pi = +0''{\cdot}28 \quad \pm 0''{\cdot}045.$$

The Constant of Precession.

For an exact determination of the Constant of Precession two sets of data are required—viz., two well-founded equinoxes and a number of stars observed near both their epochs. It is, of course, also advantageous to have the epochs separated by as long an interval of time as possible. Dr. Dreyer, in his "New Determination of the Constant of Precession" (*Copernicus*, No. 20), has made use of data which are well suited in some respects to give a useful value of the Constant. He has compared the places of about 3300 stars as given in Lalande's *Histoire Céleste* with their places as given by Schjellerup in his great Catalogue of stars situated between $+15°$ and $-15°$ Declination. Besides having such a large number of stars to form the basis of his investigation, Dr. Dreyer points out that the interval of time between the two epochs of observation is also favourable, being 66 years. Lalande's observations of stars near the equator were made during the years 1793–1801, whilst Schjellerup's observations comprise the time from Sept. 1861 to Dec. 1863. The Right Ascensions only were used, as the foundation of these appeared more secure than that of the Declinations.

For the reduction of the observed places to 1800·0 the tables of reduction by the late Von Asten were used, as in Dr. Dreyer's opinion Baily's Catalogue is useless for any purpose requiring

accuracy, and should only be used as a mere index to the stars observed by Lalande. The mean R.A.'s for 1800·0 having been computed, they were brought up to Schjellerup's epoch 1865·0 by using the mean of Baily's precessions, computed from Bessel's Constant, and of Schjellerup's precessions, computed from Struve's Constant. The comparison with Schjellerup's places was then made (all errata that could be discovered having been corrected), and the differences exceeding $0^s.7$ examined by comparing all the Catalogues at the author's disposal in order, if possible, to detect proper motion, the correction for which was applied if the quantity appeared at all trustworthy. The mean result has also to be corrected for errors in the equinoxes on which the R.A.'s are founded, and Dr. Dreyer decided to use the corrections given in Newcomb's "Equatorial Fundamental Stars," which would also make his result comparable with the older values of the Constant of Precession when reduced to Newcomb's mean homogeneous system (*V. J. S.* xiii. pp. 107–110). The residual difference is then considered as due to error in the assumed Constants. Dr. Dreyer's value of the Constant of Precession for 1800 thus determined (the supplementary quantities being taken from Peters' *Numerus Constans Nutationis*) is $50''.2365$; the older values for the same epoch, and reduced to Newcomb's system, are—

Bessel	$50''.214$
Struve	50·232
Struve-Peters	50·236
Nyrén	50·220

The new determination is not, strictly speaking, an independent one, as Lalande's R.A.'s reduced in the manner described above depend on Piazzi's observations; but as we have seen, the result agrees well with the quantities which have been previously deduced, and considering the large number of stars used and the careful manner in which the work appears to have been done, it is useful as a check on the accuracy of what is now the generally received value of the Constant of Precession.

A. M. W. D.

The Celestial Charts of Professor C. H. F. Peters.

One of the most valuable results of the discovery of minor planets has been the production of star charts of a high degree of accuracy, and comprising stars of a low order of magnitude.

The most important maps which have hitherto been published to assist these discoveries are: (1) the Berlin Academy Star Charts, which are complete for the 24 hours of Right Ascension, and contain, in 24 maps, 40,000 stars to the ninth magnitude

many of which, however, are duplicates from the maps overlapping; and (2) M. Chacornac's Ecliptic Charts, containing, in 42 maps, over 67,000 stars, down to the thirteenth magnitude; but the series for all longitudes is not yet completed. There can be little doubt also that Harding's Atlas of 60,000 stars, though ranging from the Pole to $-30°$ Declination, was likewise produced partly to assist in the fascinating search for minor planets instituted by Bode and Zach.

Professor C. H. F. Peters, of Hamilton College, Clinton—the distinguished discoverer of no less than 41 minor planets, being the greatest number yet discovered by any astronomer—has just published the first series of Zodiacal Charts, on which he has been engaged since 1860.

This first instalment of a most valuable work consists of 20 charts, each one covering 20^m in Right Ascension, and $5°$ in Declination, with overlapping margins of 1^m and $10'$ respectively. The convergence of meridians is disregarded, and a uniform equal surface projection is adopted on a scale of 60 mm. to $1°$. The maps have been carefully revised and compared with the heavens during the past fifteen months, with the result that no conspicuous star is omitted. The locality of the stars in the maps may be thus roughly summarised according to constellation.

1 Map	...	...	...	Stars in	Aries.
4 Maps	...	...	...	"	Leo.
4 "	...	...	...	"	Virgo.
1 Map	...	...	...	"	Libra.
3 Maps	...	...	...	"	Capricornus.
5 "	...	...	...	"	Aquarius.
2 "	...	...	...	"	Pisces.
20 Maps					

The epoch of the charts is 1860·0. The stars have been plotted with great care, and the author states that the position of a star may be read off with a probable error of only 3 seconds in R.A. and $0'\cdot2$ in Declination. His desire was to represent portions of the sky in a picture that in future ages might serve as a sure basis for drawing conclusions as to changes going on in the starry heavens; and for that purpose to make as accurate and complete a delineation as the 13-inch Refractor of the Litchfield Observatory with a power of 80 would permit. This shows stars down to the fourteenth magnitude. The magnitudes of the stars in the charts are approximately indicated by the size of the disk.

Assuming No. 1 chart to be an average one, then the total number of different stars whose positions are plotted in the above 20 maps will be about 38,000. The maps have been reproduced

from the originals by photolithography, so that no error of copying has crept in.

The whole of the work, observations, reductions, and drafting, has been done by Prof. Peters without any assistance, and it is published at his own expense for gratuitous distribution.

The magnitude of the work, and the unwearied perseverance and labour necessary to complete it, and the practical result that has followed by the author's discovery of such a large number of minor planets, redound greatly to his honour and credit. Astronomers are under a great obligation to Professor Peters for the work he has just published. The value of it must be enduring, and it is therefore much to be hoped that his generous mode of distribution of copies may be modified, so that astronomers generally may be able to obtain a work that must always be useful, and in many cases absolutely indispensable.

The Mass of Jupiter.

Dr. Wilhelm Schur has published (*Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher.* Band xlv. No. 3) a very valuable determination of this important astronomical constant derived from heliometer measures of the satellites made at Strassburg, during the years 1874, 1876, 1879, and 1880. Altogether four heliometers (lent for the use of the German Transit of *Venus* Expedition of 1874) were employed in the research—viz., those belonging to the Observatories of Breslau, Gotha (since transferred to Strassburg), Göttingen, and Berlin. These instruments are of the same size and power.

Dr. Schur seems to have made excellent use of his opportunities, as he has secured 176 measures of distances, and 154 measures of position-angles of the four satellites. These measures have been reduced in the most careful and elaborate manner, and corrections to the elements of the orbits of the satellites obtained. Finally Dr. Schur is led to the corrected values of the mean distances of the satellites from their primary, whence the value of the mass is immediately deduced. The following are Dr. Schur's results:—

Satellite.	Reciprocal of Mass.
I.	1050·918 ± 1·125
II.	1046·026 ± 0·962
III.	1047·665 ± 0·436
IV.	1046·818 ± 0·327

Combining these by weight, the reciprocal of the mass of *Jupiter* is 1047·232 ± 0·246. The value obtained by Bessel from observations with the Königsberg heliometer was 1047·879.

This result, however, requires to be corrected for the effect of temperature, the periodic error of the micrometer screw, and for the error of the assumed value of a revolution of the screw. Dr. Schur has accordingly re-reduced Bessel's observations, taking account of these corrections, and deduced the result 1048·629, or 1047·905 (the latter of which he considers final), according to the screw value adopted. In this memoir the author has also discussed the observations of E. Luther, Triesnecker, and Santini, and deduced a value of *Jupiter's* mass from each. Finally he gives a comparison between the values of the reciprocal of the mass deduced from measures of the satellites and from planetary perturbations, the mean of the former being 1048·27, and of the latter 1049·53. Further, it is to be remarked that if Nicolai's value (1053·92) deduced from perturbations of *Juno* be rejected, all the other modern determinations range between 1047 and 1051; between which limits we may with great confidence assume the true value to lie.

Dr. Schur deserves the gratitude of astronomers for the care and assiduity with which he has pursued his investigations. It is only by continued labours of this kind that we can gradually approximate to a knowledge of the exact values of astronomical constants. A. M. W. D.

Professor Holden's Monograph of the Nebula of Orion.

The Washington Observations for 1878 contain a very important and exhaustive monograph of the central parts of the nebula of *Orion* by Professor Edward S. Holden. The author states that the main object of the Memoir is to leave such measures and descriptions of the brightest parts of the nebula of *Orion* as shall enable another person observing in after years, with the same telescope under like conditions, to say with certainty whether or no changes have occurred in these parts of this nebula. His further object was to thoroughly discuss the vast mass of material now on hand.

Before discussing the old observations it was necessary to fix upon one system of nomenclature. For the stars in the central part of the nebula, Professor Holden has adopted Bond's Catalogue reduced to 1877·0. It being also equally necessary that a rather minute system of nomenclature should be adopted to distinguish the various bright masses, dark channels, spirals, &c., of the central portion of the nebula, an Index Map is given whereon the various portions are indicated by various letters. This map is unfortunately not so clear as it might be. The boundaries of different portions are shown by white lines upon black, and it is difficult to identify a particular spot. Two or three nomenclatures of other astronomers are combined and indicated by underscoring letters or inclosing them in a right

angle, which gives a rather confused appearance. In his Introduction the author gives a list of the more important books and memoirs relating to the nebula of *Orion*, a list of drawings referred to, and of the telescopes employed to observe the nebula.

Professor Holden truly says that probably no object outside the solar system has received more attention than this nebula, and where such a mass of observations is in existence it is difficult to discriminate. No labour has been spared by the author in his endeavour to bring together reliable copies of all known drawings and copious extracts from the original observations.

Wood-cuts of the original drawings are given, all upon the same scale—that is to say, the original drawings were photographed on a scale of one inch, equal to the distance between Bond's two stars 685 and 741, or about 129 seconds of arc. Drawings made by reflectors are inverted, so that all are immediately comparable. This an important advantage, and differences and resemblances in the drawings thus become conspicuous which otherwise might escape attention; exception must however be taken to the unsatisfactory manner in which some of the wood-cuts are executed—that of Sir John Herschel's beautiful Cape drawing, for example, is very unlike the original, and could not be used for comparison. The work gives thirty-eight drawings engraved nearly on the same scale, and a reproduction of the exquisite steel-engraving of G. P. Bond, which the author considers as the most satisfactory representation of any celestial object which has yet been produced, and entirely above criticism.

The work commences with a history of the various researches on the nebula of *Orion* in chronological order, beginning with the first recorded notice of it by Cysatus in 1619, and followed by a full and complete discussion of all observations of importance from that time to the present day. The amount of laborious research required to produce such an exhaustive history must have been very great, and the result is of high value. Particular attention has been devoted to the observations of the two Herschels, Schroeter, the two Bonds, Liaponoff and Struve, Lassell, Rosse, Secchi, and D'Arrest. This portion of the work will always be of great importance as an exhaustive *résumé* of what has been observed.

The second part of the work is devoted to Professor Holden's own observations of the nebula of *Orion* made at Washington with the 26-inch telescope. These observations were commenced in 1874, and continued to 1880. They consist of eye-observations of the form, position, and relative brightness of different portions of the nebula, and micrometric measures of the position of channels and masses of the nebula relatively to stars. Particular attention was also paid to the variability of stars. On this point the author remarks that never, under the most favourable circumstances, were any stars or points of light seen or

suspected within the trapezium. The eye-observations of relative brightness of different portions of the nebula are summarised and discussed, and compared with a series of photometric observations made with a Hastings Nebula Photometer, which show agreement.

Part III. contains a summary of all the observations 1656 to 1880, discussing the connection between the nebula of *Orion* and its contained stars, the order of brightness of the various masses, and a detailed history of each mass.

The principal conclusions to which Professor Holden comes from the above discussion are :—

1. That there have been changes in the brightness of certain masses. Certain of the masses have varied in brightness during the period of the Washington observations (1874–1880). A new nebulous patch has been seen from the time of its origin, when it was stellar in appearance and faint, until now, when it is bright and of measurable dimensions.

2. That there is no evidence whatever for any change of form. The figure of the nebula of *Orion* has remained the same from 1758 to now.

Professor Holden's valuable monograph is ornamented by a photolithograph of the late Dr. Henry Draper's beautiful photograph of the nebula of *Orion*. It is impossible to discuss such an investigation as Professor Holden has undertaken without seeing that the photographic results of Dr. Draper, and the still more marvellous photographs of this nebula obtained by Mr. Common, afford far sounder and more reliable records for determining any change either in form, relative brightness, or relative position with regard to the stars than can be obtained from the examination of any eye-drawings, however carefully produced.

In an appendix to the Washington observations for 1877, Professor Holden has discussed the micrometric measurements of the six stars in the Trapezium made by Professor Hall in 1877–78, compared with those of other observers. The conclusion come to from a long and careful discussion is that after making due allowance for the unavoidable accidental and systematic errors, the comparison of all measures of the six stars of this system show their probable physical association.

Professor Holden deserves the thanks of astronomers for the painstaking and laborious research he has made into all the observations on the old method, and he is to be congratulated on bringing his labours to so successful a termination.

Professor Langley's Researches on Solar Radiation.

At the last meeting of the British Association, and also later at the French Academy, Professor Langley gave a preliminary account of the measurements he had made of the energy of radiation of the solar spectrum. The importance of this work is worthy

of more than a passing remark, since it deals not only with those radiations which are visible, but also with the radiations which have large wave-length, and whose energy is more than two-thirds of the total energy of solar radiation. Prof. Langley had first to make an instrument to carry out his researches, and the instrument required had to be excessively sensitive to radiation and also excessively exact. This instrument he completely worked out, and gave it the name of the Bolometer. As with a thermopile, the heating power of radiation is measured by deflection of a sensitive galvanometer needle; it however differs widely in every other respect. Broadly speaking, the Bolometer is made on the same principle as a Siemens' Pyrometer or a Wheatstone's Bridge, an alteration in the temperature of one of the conducting branches causing a current to pass through the coils of the galvanometer. Its sensitiveness depends on the excessive thinness of the strip of platinum or iron on which the radiation falls, and which forms part of the divided circuit. Its delicacy is such that it will show a rise in temperature in the wire of $\frac{1}{10000}$° Fahr., and when used in an ordinary manner is twenty times more sensitive than a thermopile.

With this Bolometer Prof. Langley has worked on the solar spectrum at sea-level, and at altitudes up to 10,000 feet, and he finds in all cases that the energy curve so obtained is interrupted by breaks in the invisible part of the spectrum similar to those in the visible part. His energy curves extend as far as λ 28,000, and even at this extreme limit the spectrum is traversed by bands of absorption which, by analogy and comparison with Capt. Abney's map, obtained by means of photography, and which extends to λ 12,000, he surmises to be made up of linear absorptions. These absorptions appear to be undiminished at a high altitude, confirming in a remarkable manner the observations made also at a high altitude by the latter observer, thus showing that the cause of these absorptions is to be looked for outside our atmosphere. Another point which Prof. Langley seems to have clearly demonstrated is the untrustworthiness of Cauchy's formula for dispersion. If this formula were correct, the limit of the prismatic spectrum should be nearly as much below A as E is above it. He has, however, mapped the prismatic spectrum for a distance below A as far as G is above it. This result is remarkable, since to λ 12,000 the formula holds fairly well, but beyond that point the approximate accuracy ceases, and, as Lord Rayleigh remarked at the British Association, this will necessitate a reconsideration of the properties of the ether. The establishment of this failure of Cauchy's theory was made by an ingenious combination of a diffraction grating and a prism. The grating was one of Prof. Rowland's new concave gratings of 5,000 lines to the inch, the radius of curvature being about five feet. The spectra were formed by this grating and a slit. A small slice of the superposed spectra of the different orders was then allowed to fall on a

prism which sorted out the different spectra, and then the Bolometer measured each differently refracted radiation. The energy curve thus obtained was compared with the curve obtained from the prism alone, with the result already recorded.

A comparison of the curves obtained at sea-level and at Mount Whitney, in South California, has led Prof. Langley to conclude that solar light, before it reaches our atmosphere, is decidedly bluer than we perceive it, and that its original colour is of a tint corresponding generally with that of the solar spectrum about F. These researches, which have been carried out in some cases under most trying circumstances and amidst much discomfort, are perhaps some of the most important which have been recorded during the past year, and we may expect that when fuller details are published we shall have data which will go a long way towards enabling us to calculate the average temperature of our great source of radiation.

Dr. Huggins' Method of Photographing the Solar Corona without an Eclipse.

The photograph of the spectrum of the corona taken by Professor Schuster in Egypt during the eclipse of May 17, 1882, showed that the coronal light is strongest in the part of the spectrum between G and H. This fact has led Dr. Huggins to a method of photographing the corona without an eclipse by the use of screens of coloured glass or fluid which would limit the light received by the plate to the part of the spectrum between G and H, and thus enable the coronal light to hold its own against the atmospheric glare. In applying the method, Dr. Huggins used a Newtonian reflector of 6 inches aperture and 3½ feet focal length, with three or four plates of violet glass immediately in front of the photographic plate. In his later experiments he substituted for the violet glass a strong solution of permanganate of potash in a glass cell. Twenty successful photographs were obtained between June and September 28, in all of which Dr. Huggins considers that the coronal form is exhibited by the curved rays and rifts characteristic of the corona. Different times of exposure were given, the plates with very short exposure showing the inner corona only, whilst in those with longest exposure not only the Sun but the corona also is photographically reversed. Dr. Huggins has compared the plates taken on different days with different absorptive media interposed and with the Sun in different parts of the field, and finds that they agree *inter se*, and also with the photographs of the corona taken in Egypt during the eclipse of May last. The average heights of the inner and outer corona in the eclipse photographs were also found to be the same as in Dr. Huggins' plates. Capt. Abney has also come to the conclusion, after careful examination, that the rifts

and streamers in these plates have the same position and form as in the eclipse photographs, and that the coronal appearances are no more due to instrumental causes in the one case than in the other. Accepting this evidence of the reality of the coronal appearances on these photographs, "there can be little doubt," Dr. Huggins thinks, "that by his method under better conditions of climate, and especially at considerable elevations, the corona may be successfully photographed from day to day with a definiteness which would allow of the study of the changes which are doubtlessly always going on in it. By an adjustment of the times of exposure, the inner or outer corona could be obtained as might be desired." W. H. M. C.

The Total Solar Eclipse of 1882 *May* 17.

During the eclipse of May 17 a series of spectroscopic eye observations were made by Mr. Lockyer, especially at the beginning and end of totality. The arrangements for photographic work were made by Captain Abney, but as he was prevented from joining the expedition, Dr. Schuster took charge of that part of the work.

The chief object of the expedition was to obtain photographs of the spectrum of the corona and prominences. A series of photographs of the corona itself was also taken with exposures varying from 3 to 22 seconds. These photographs show the detailed structure of the corona, as well as an image of the comet which was visible during the eclipse, in the neighbourhood of the Sun. The photographs obtained with a complete spectroscope show, in the first place, a complicated spectrum of one of the prominences, extending far into the ultra-violet, and exhibiting, in addition to the hydrogen lines, lines of calcium and some other unknown lines. The light due to the calcium lines H and K is so bright that it is scattered in our atmosphere with sufficient intensity and appears right across the surface of the Moon.

The spectrum of the corona close to the Sun's limb is chiefly continuous, but at some distance away from the Sun a sudden decrease in the intensity of the continuous spectrum is noticed, and beyond that point many faint lines make their appearance. The solar line G is also seen to be reversed in the outer parts of the corona.

An interesting photograph was also obtained by means of the prismatic camera, which is an ordinary photographic camera with a prism placed in front of the lens. The spectrum of different prominences can be studied in the photograph thus obtained, and interesting differences between the prominences have been brought to light. The plate exposed in this instrument was sensitive in the red, and an impression reaching far

into the infra-red has been secured. Continuous rings of light corresponding to the corona line K 1474 and to D_3 are also seen independently of the prominences. A. S.

Astronomical Photography.

The past year has been signalised by the successful application of the improved dry-plate processes of photography to nebulæ as well as to comets. Dr. Huggins has obtained a photograph of the spectrum of the nebula in *Orion* with an exposure of 45 minutes, using the same spectroscope and 18-inch reflector which he employed for his photographs of star-spectra. This photograph shows a very strong bright line in the ultra-violet at wave-length 3730, in addition to the four nebular lines previously discovered by him in the visible part of the spectrum. There is also a very faint continuous spectrum, probably due to stellar light. Subsequently the late Professor H. Draper also succeeded in photographing the spectrum of this nebula. On his photographs the hydrogen line near G (λ 4340) is strong and sharp, h (λ 4101) is more delicate, and there are faint traces of other lines in the violet, but the strong line at λ 3730 is not shown. Professor Draper considers the most striking feature of the photographs to be the discovery of two condensed portions of the nebula just preceding the trapezium, which give a continuous spectrum.

Professor H. Draper has also obtained successful photographs of the nebula itself, containing most of the delicate outlying parts. More recently Mr. Common has taken photographs with his 36-inch reflector, which show all the detail visible in the best drawings, as well as the faintest stars which have been mapped.

The spectrum of Comet *a* 1882 (Wells) was photographed by Dr. Huggins on May 31. It differs greatly in the photographic portion, as in the visible part, from that of Comet *b* 1881, the cyanogen group beginning at λ 3883, and the two other groups between G and h and between h and H being absent. The continuous spectrum extends from F to a little beyond H, but does not show the Fraunhofer lines, though the lines G, H, and K are clearly seen in the spectrum of *a Ursæ Majoris* taken for comparison on the plate under the same conditions. From this Dr. Huggins infers that the part of this comet's light which gives a continuous spectrum must have been much stronger relatively to the sunlight reflected than in the case of Comet *b* 1881. In the continuous spectrum from the nucleus there are at least five places of greater brightness at λ 4769, 4634, 4507, 4412, and 4253. These are doubtless groups of bright lines, and they extend also into the coma on the side next the Sun, where the continuous spectrum is very much fainter. W. H. M. C.

On Small Displacements of the Plumb-line.

Some account was given in last year's Report of the experiments of Mr. G. H. Darwin and Mr. Horace Darwin with an instrument adapted for detecting very small changes in the vertical. It appears from their Second Report to the British Association, which is drawn up by Mr. G. H. Darwin, that the work of the experimenters has not been resumed during the past year. It will be remembered that the measurement of the lunar disturbance of gravity was found to be impracticable, and that the investigation had branched off into considerations of small changes in the vertical. The first part of this Second Report contains an account of the work of a number of Italian observers —Bertelli, Rossi, and others—in this field. The Italians commenced their observations with the intention of investigating earthquakes, and found that one branch of their subject led them on to consider slower changes in the vertical. It appears that the phenomena observed in England by the Darwins were very similar to those observed in Italy; the only important difference being the frequency of sensible earthquake shocks in the latter country.

The second part of the Report contains a mathematical investigation of the disturbance of the vertical, which may arise through the elastic yielding of the Earth's surface when the barometric pressure varies and when the tides rise and fall. The investigation is based on the hypothesis that the upper strata of the Earth are formed of an elastic solid, and numerical results are given on the supposition that the rigidity of the solid is somewhat greater than that of glass.

It is proved that the slope caused by elastic yielding at any point of the surface must be exactly proportional to the deflection of the vertical due to the attraction of the weight producing that slope. To the observer these two changes would merge into one another, and the only fact observed would be an apparent deflection of the vertical. Taking certain moderate estimates of the value of barometric gradient, it appears that the amplitude of the apparent deflection of the vertical might amount to $0''\cdot03$. As this is greater than the computed amplitude of deflection due directly to the Moon's attraction, it is concluded by the author as very improbable that any instrument on the Earth's surface would enable us to measure the lunar disturbance of gravity.

The next point investigated is the amount of deflection of the vertical which may be expected to result from the rise and fall of tide at places of observation near the coasts of continents. The computed deflections are considerably more than result from variations of barometric pressure, and might be sufficiently great to produce even astronomically sensible results at observatories

situated very close to the coast. Even many miles inland they would be sufficiently great in amount to be easily detected by special instruments for that purpose. The author considers, however, that it is probable that such changes would be to a large extent masked by the larger changes of a seismic origin, occurring simultaneously.

He therefore concludes that the results of observations with *exceedingly* delicate instruments are not likely to prove of much value, but the records would be likely to present a chaos of incessant changes, of which no satisfactory account could ever be given.

He considers, however, that the use of somewhat coarser instruments (such as those of the Italians) may lead to important results concerning the seismic and slower quasi-seismic changes taking place in the upper strata of the Earth.

Investigations Relating to the Tides.

Mr. G. H. Darwin also presented two other papers relating to the Tides to the British Association at the late meeting at Southampton. The first of these has reference to the method of reduction employed in deducing the values of the tides of long period from the records of tidal observation. We need here only mention that, in consequence of a mistake (detected by Prof. J. C. Adams), the published results assign a value to the synodic fortnightly tide which is fictitious. It is proposed that these results should be corrected under the supervision of a committee consisting of Prof. Adams and Mr. Darwin.

The other paper is the abstract of an investigation contributed to the new edition of Thomson and Tait's *Natural Philosophy*, now in the press. The values of the lunar fortnightly and the elliptic monthly tides, as observed at a number of stations and in a series of years, are reduced by the method of least squares, and the result shows that it is probable that the height of those tides is about two-thirds of what it would be if the Earth's mass were absolutely rigid.

From this it may be concluded as probable that the Earth as a whole has at least as great a modulus of rigidity as if it were formed of steel. Although the number of observations is considerable, being thirty-three for each class of tide, yet the concordance between the results for different years and different places is not very satisfactory, and it will be necessary to await the accumulation of more results at places more widely scattered over the Earth's surface to evaluate exactly the degree of rigidity possessed by the Earth's mass.

Oppolzer's Treatise on the Calculation of the Orbits of Comets and Planets.

The first volume of Professor Oppolzer's *Lehrbuch zur Bahnbestimmung der Kometen und Planeten* was issued in 1870, and the second volume in 1879; and a notice of the complete work appeared in the Annual Report for 1880 (vol. xl. p. 243). The first volume contained 353 large octavo pages, and the second 635, and we have now to mention that a second edition of the first volume, containing 683 pages, has just been published. The original first volume of 1870 is thus entirely superseded, and the work, as a whole, consists of the volumes of 1879 and 1882, containing in all more than 1300 pages. The first volume relates to the coordinates in their mutual relations and their relations to the time, with full applications of the methods of taking account of Aberration, Precession, Nutation, &c., and to the determination of parabolic orbits and orbits in general in which no supposition is made with regard to the eccentricity. There are about 250 pages of tables in the volume, the largest of which is a modified Barker's table giving log M, where

$$M = \frac{\sqrt{2}}{k} \tan \tfrac{1}{2} v + \tfrac{1}{3} \frac{\sqrt{2}}{k} \tan^3 \tfrac{1}{2} v$$

which was calculated for the work.

All the formulæ and processes and tables are given with abundant fulness and detail, and the work, as a whole, is quite unique in astronomical literature. It is an elaborate and complete treatise on the very part of mathematical astronomy which most required comprehensive treatment in a single work, and which seemed to have but very slight chance of obtaining it. The book is beautifully printed and got up in every way, and Dr. Oppolzer has earned the congratulations and thanks of those interested in astronomical calculation, on which he has conferred a real service.

Bibliography of Astronomy.

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1. Independent and separately-published works on astronomy.
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The vast mass of scientific work at the present day is to be found in the publications of learned Societies; and so MM. Houzeau and Lancaster have wisely commenced the publication of the work with the second volume. A very cursory examination of it is enough to indicate the enormous labour involved in the undertaking, and a careful study of it reveals that the research has been carried out in a minute and exhaustive manner which reflects the greatest credit upon the authors and puts astronomers under a lasting obligation to them.

In a work of this magnitude the method of arrangement, and the facility afforded by it for finding a research on a particular subject, is of vital importance to its utility.

The volume under consideration is divided into nine sections.

1. The History and Study of Astronomy .	Comprising	17	chapters
2. Astronomical Biographies	„	2	„
3. Spherical Astronomy	„	34	„
4. Theoretical Astronomy...	„	14	„
5. Celestial Mechanics	„	14	„
6. Physical Astronomy	„	47	„
7. Practical Astronomy	„	31	„
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Further spectroscopic observations of Comet *a*, 1882 (Wells), made at the Royal Observatory, Greenwich. Astronomer Royal.

Curves showing the changes in the adopted diameter of the Moon as given by the observations in the Greenwich Lunar Reductions 1750 to 1830. E. J. Stone.

Elements of Comet *Wells* obtained graphically. F. C. Penrose.

Nov. 10. Ephemerides of the satellites of *Saturn*, August to November 1882. A. Marth.

Ephemeris of the satellite of *Neptune*, 1882–1883. A. Marth.

Observations of Comet *a*, 1882, made at the Radcliffe Observatory, Oxford. E. J. Stone.

On the partial eclipse of the Sun, 1882, May 17, observed at Vizagapatam. A. V. Nursing Row.

Observation of Comet *Wells*. L. G. Puckle.

Spectroscopic observations of Comet *Wells*. Dr. de Konkoly.

Ephemerides of the satellites of *Saturn*, December 1882 to March 1883. A. Marth.

Addition to the Ephemeris for physical observations of *Jupiter*: on the motion of the white spot. A. Marth.

Réponse à M. Marth. M. Loewy.

On the solution of Kepler's problem. Professor C. V. Zenger.

Observations of Comet *b*, 1882, made at Windsor, New South Wales. J. Tebbutt.

Elements of Comet *b*, 1882. W. H. Finlay and W. L. Elkin.

The fireball radiants of August 9–11. W. F. Denning.

The electric light in observatories. W. S. Franks.

The markings on *Jupiter*. W. F. Denning.

Elements of Comet III. (Schäberle), 1881. H. T. Vivian.

On observations of Comets 1881 I. and II., of Wells's Comet, and of the Great Comet (*b*) 1882, made at the Royal Observatory, Cape of Good Hope. David Gill.

Notes on the Great Comet (*b*) 1882. David Gill.

The Great Comet (*b*) 1882: disappearance at the Sun's limb. W. H. Finlay.

Observations of the Great Comet (*b*) 1882. W. L. Elkin.

On a probable Assyrian Transit of *Venus*. Rev. S. J. Johnson.

The Great Comet (*b*) 1882. F. C. Penrose.

On certain deviations from the law of apertures in relation to stellar photometry, and on the applicability of a glass wedge to the determination of the magnitudes of coloured stars. Professor C. Pritchard.

Observations of Comets *a*, *b*, and *c*, 1882, made at the Royal Observatory, Greenwich. Astronomer Royal.

The solar eclipse of 1882, May 17, observed at Meerut, India. Major A. Burton-Brown.

Sextant observations of the Great Comet (*b*) 1882. Captain G. Pochrane.

Dec. 8 Observations of the Great Comet (*b*) 1882, made at the Melbourne Observatory. R. L. J. Ellery.

Observations of the Great Comet (*b*) 1882, made at the Sydney Observatory. H. C. Russell.

Observations of Comet *Wells* (*a*) 1882, made at Windsor, New South Wales. J. Tebbutt.

Observations of the Great Comet (*b*) 1882. A. V. Nursing Row.

Observations of the Great Comet (*b*) 1882 (extract from a letter to the Rev T. W. Webb). J. T. Stevenson.

Observations of the Great Comet (*b*) 1882, made at the Observatory, O'Gyalla, Hungary. Dr. N. de Konkoly.

The star gauges of Sir W. Herschel, reduced to 1860. Prof. E. S. Holden.

On photographs of the Great Comet (*b*) 1882, obtained at the Royal Observatory, Cape of Good Hope. David Gill.

Observation of the Transit of *Venus* 1882, December 6, made at Crowborough, Tunbridge Wells. C. L. Prince.

Observations of the Great Comet (*b*) 1882, made at the Cambridge Observatory. Prof. J. C. Adams.

On Newton's solution of Kepler's problem. Prof. J. C. Adams.

Observations of the Great Comet (*b*) 1882. Rev. J. Reed.

Observation of the Transit of *Venus* 1882, December
1883. 6. W. E. Cooper.

Jan. 12. Ephemeris of the satellites of *Uranus*, 1883. A. Marth.

Observation of the Transit of *Venus* 1882, December 6, made at the Glasgow Observatory. Prof. R. Grant.

The Transit of *Venus* 1882, December 6, observed at the Allegheny Observatory. Prof. S. P. Langley.

Observations of the solar spots, November 1882. F. Brodie.

Observation of the Transit of *Venus* 1882, December 6, made at Fernhill, Isle of Wight. F. Brodie.

The Aquariads of April 29 to May 3. W. F. Denning.

Observations of the Great Comet (*b*) 1882. B. J. Hopkins.

Le passage de *Vénus* (1882, Dec. 6) observé à l'Observatoire, Moncalieri. F. Denza.

Physical observations of the Great Comet (*b*) 1882. C. L. Prince.

Sextant observations of the Great Comet (*b*) 1882, made on board the ship "Earnock." Capt. G. F. Parson.

Sextant observations of the Great Comet (*b*) 1882, made on board the ship "Superb." Capt. D. W. Barker.

Observation of the Transit of *Venus* 1882, December 6, made on board H.M.S. "Northampton" at Antigua, West Indies. J. R. Walker (and other officers).

Observation of the Transit of *Venus* 1882, December 6, at Marseilles. Rev. S. J. Johnson.

Observation of the Transit of *Venus*, 1882, December 6. Rev. R. P. Davies.

Observations of phenomena of *Jupiter's* satellites, made at the University Observatory, Durham, in the year 1882. G. A. Goldney.

Postscript on a communication made to the Royal Astronomical Society in November last, on stellar photometry. Prof. C. Pritchard.

Observations of *Jupiter*. W. F. Denning.

The Great Comet (*b*) 1882. L. A. Eddie.

Observation of the Transit of *Venus* 1882, December 6, made near Bath. M. Horner.

Reduction of latitude and logarithm of the Earth's radius, with Col. Clarke's value of the Earth's compression. E. J. Stone.

Meteors and meteorology. R. A. Proctor.

The orbit of the Great Comet (*b*) 1882. F. C. Penrose.

Note upon the longitude of Madras, Singapore, and Batavia. Prof. J. A. C. Oudemans.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1882. No. VI. Astronomer Royal.

The spectrum of the great Sun-spot of 1882, November 12–25, observed at the Royal Observatory, Greenwich. Astronomer Royal.

Note on William Ball's observations of *Saturn*. Prof. J. C. Adams.

List of Public Institutions and of Persons who have contributed to the Library &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Norwegian Government.
The Lords Commissioners of the Admiralty.
British Association for the Advancement of Science.
British Horological Institute.
Geological Society of London.
Institute of Actuaries.
Meteorological Office.
Meteorological Society.
Photographic Society of Great Britain.
Physical Society of London.
Royal Asiatic Society.
Royal Geographical Society.
Royal Institution.
Royal Observatory, Greenwich.
Royal Society of London.
Royal United Service Institution.
Selenographical Society.
Society of Arts.
University College, London.
Zoological Society of London.
Bedfordshire Natural History Society.
Belfast Natural History and Philosophical Society.
Bristol Museum and Library.
Dublin, Royal Irish Academy.
Royal Dublin Society.
Dunsink Observatory.
Edinburgh, Royal Society.
Glasgow, Mitchell Library.
Glasgow Philosophical Society.
Leeds Philosophical and Literary Society.
Liverpool Free Public Library.
Liverpool Observatory.
Oxford, Radcliffe Library.
Oxford, University Observatory.
Rugby School Natural History Society.
Adelaide Observatory.
Baltimore, Johns Hopkins University.
Batavia Magnetical and Meteorological Observatory.

Berlin, Physical Society.
Berlin, Royal Academy of Sciences.
Berlin, Royal Observatory.
Berlin, Royal Prussian Geodetic Institute.
Berne, Central Meteorological Institute.
Bologna, Academy of Sciences.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Boston Scientific Society.
Brussels, Royal Observatory.
Buda-Pesth, Hungarian Academy of Sciences.
Calcutta, Asiatic Society of Bengal.
Cape Town, South African Philosophical Society.
Chapultepec Observatory.
Cherbourg, National Society of Sciences.
Chicago, Dearborn Observatory.
Cincinnati Observatory.
Cincinnati, Ohio Mechanics' Institute.
Coimbra, Observatory of the University.
Connecticut Academy.
Copenhagen, Royal Academy of Sciences.
Cordoba, National Argentine Observatory.
Geneva Observatory.
Geneva, Society of Physics and Natural History.
Genoa, Society of Literature and Science.
Göttingen, Royal Society of Sciences.
Haarlem, Musée Teyler.
Halle, Imperial Leopold-Caroline Academy.
Harvard College Astronomical Observatory.
Helsingfors, Finnish Society of Sciences.
Leghorn, Technical and Nautical Institute.
Leipzig, Astronomische Gesellschaft.
Leipzig, Royal Saxon Society of Sciences.
Lisbon Geographical Society.
Madison, Washburn Observatory.
Melbourne Observatory.
Melbourne, Royal Society of Victoria.
Milan, Royal Observatory.
Moncalieri Observatory.
Montreal, Geological Survey of Canada.
Moscow Observatory.
Mozambique Geographical Society.
Munich, Royal Bavarian Academy.
Munich, Royal Observatory.
Neuchatel, Society of Natural Sciences.
New York, Astor Library.
Ottawa, Canadian Meteorological Office.
Padua Observatory.
Palermo Observatory.
Paris, Academy of Sciences.

Paris, Bureau des Longitudes.
Paris, Dépôt Général de la Marine.
Paris, Ecole Polytechnique.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Prague Observatory.
Pulkowa Observatory.
Rio de Janeiro, Imperial Observatory.
Rome, Italian Meteoric Association.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy dei Lincei.
Rome, Royal Academy dei Lincei.
St. Petersburg, Imperial Academy of Sciences.
St. Petersburg, International Polar Commission.
San Fernando Observatory.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tasmania, Royal Society.
Tiflis, Physical Observatory.
Toulouse, Academy of Sciences.
Turin, Italian Meteorological Association.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Washington, Smithsonian Institution.
Washington, United States Chief Signal Office.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale College Observatory.
Yokohama, Seismological Society of Japan.
Editors of the American Journal of Science.
Editors of the American Journal of Mathematics.
Editor of the Analyst.
Editor of the Astronomical Register.
Editor of the Astronomische Nachrichten.
Editor of the Athenæum.
Editors of the Bulletin des Sciences Mathématiques, &c.
Editor of the English Mechanic.
Editor of the Journal of Science.
Editor of Die Naturforscher.
Editors of the Observatory.
Editors of La Revue Scientifique.
Editor of Sirius.
Editor of the Sidereal Messenger.

Capt. W. de W. Abney.
Sir G. B. Airy.
Prof. J. J. Åstrand.
F. Barrow, Esq.
Prof. Bakhuyzen.
Dr. L. de Ball.
Dr. L. Becker.
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Dr. K. Bohlin.
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C. E. Burton, Esq.
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Capt. J. E. Cole.
A. A. Common, Esq.
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W. Crellin, Esq.
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Padre F. Denza.
Dr. W. Doberck.
Dr. H. Draper.
W. Ellis, Esq.
Mons. F. Engström.
Sigr. G. Ferrari.
Mons. Ch. Fiévez.
Mons. C. Flammarion.
Rev. A. Freeman.
David Gill, Esq.
Dr. H. Gyldén.
Prof. A. Hall.
Maxwell Hall, Esq.
Prof. E. S. Holden.
Prof. J. C. Houzeau.
Mons. J. Janssen.
Dr. S. Kinns.
Dr. N. de Konkoly.
Prof. S. P. Langley.
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H. C. Lewis, Esq.
Prof. Loomis.
Dr. G. Lorenzoni.
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Messrs. Macmillan & Co.
Dr. W. Meyer.
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Dr. C. H. F. Peters.
Prof. E. C. Pickering.
H. Pratt, Esq.
C. L. Prince, Esq.
A. Ramsay, Esq.
A. C. Ranyard, Esq.
Rev. W. J. B. Richards.
The Earl of Rosse.
H. C. Russell, Esq.
H. Sadler, Esq.
E. Sang, Esq.
Sigr. G. V. Schiaparelli.
Dr. H. Schur.
Mons. Th. Schwedoff.
Dr. H. Seeliger.
Rev. E. L. Slafter.
Prof. C. P. Smyth.
Major G. Strahan.
Prof. O. von Struve.
Prof. P. Tacchini.
John Tebbutt, Esq.
Dr. F. Terby.
Mons. S. Tromholt.
Mons. Y. Villarceau.
Dr. G. D. E. Weyer.
Dr. R. Wolf.

ADDRESS

Delivered by the President on Presenting the Gold Medal of the Society to Dr. Benjamin Apthorp Gould.

GENTLEMEN,—

Your Council have awarded the Gold Medal of the Society to Benjamin Apthorp Gould for his *Uranometria Argentina.*

Dr. Gould is an astronomer who has held a leading position amongst the cultivators of our science for many years; and a reference to the "Royal Society's Lists of Scientific Papers" will find him credited with no less than fifty-five papers. These papers treat of almost all branches of our science; and some of them, such as the "Reduction of D'Agelet's Observations," are works of considerable extent and of great value. These works cannot have been without their influence in guiding the decision of your Council in the award of the Medal, but it has been upon Dr. Gould's direction of the work of the Cordoba Observatory that attention has been chiefly concentrated.

The astronomical results contained in the *Uranometria Argentina* constitute but a small, and in my opinion not the most valuable, portion of those which have been obtained by Dr. Gould since he assumed the direction of the Cordoba Observatory; but although the observations for the Southern Zones are understood to have been completed, and one volume of results has already been published, your Council have thought it undesirable to await the complete publication of these results before marking, in the most emphatic manner in their power, their high appreciation of the skill and energy with which Dr. Gould has utilised the resources placed at his disposal by the liberality of the Government of the Argentine Republic.

The work for which the Medal has been chiefly awarded may be considered an extension of Argelander's scale of magnitudes to all the stars which can be seen by a good eye without instrumental aid between 10° North Declination and the South Pole, together with a series of charts exhibiting, on a stereographic projection, the positions of all these stars to the sixth magnitude, and a proposed revision of the boundaries of the southern constellations.

The work is of a class which is not usually undertaken at our principal Observatories, for it requires neither an elaborate instrumental equipment nor that technical skill on the part of the observers which can only be acquired by long continued practice; but Dr. Gould, on his arrival, with four assistants, at Cordoba, in the September of 1870, found that the instruments

which had been ordered from Europe for the Observatory had not been received; and the disorganisation of scientific matters on the Continent from the war then in progress rendered it probable that there might be some considerable delay before these instruments could be delivered. Under these circumstances Dr. Gould, encouraged by the experience which he had gained, and by the success which had attended a somewhat similar effort, on a smaller scale, made during the mounting of the Transit Circle at the Albany Observatory in 1858, determined to undertake the work for which your Medal is this day awarded.

In the absence of any standard of absolute brightness, the determination of stellar magnitudes can only be relative, and the scale in which they are expressed must be an arbitrary one. The second Herschel, whilst at the Cape, determined the light received from the principal Southern stars in terms of the combined light of α^1 and α^2 *Centauri* as an unit, and he pointed out that by a slight modification of the scale in general use it would be possible to make that scale a photometric one, and the amount of light received inversely proportional to the square of the number which expressed the magnitude. But although some such modification as that proposed by Herschel would be a decided improvement, if the ground were not already preoccupied, yet our conventional system of magnitudes, as practically exhibited with some approach to scientific precision in the *Uranometria Nova*, has received such general acceptance from astronomers that probably Dr. Gould was well advised in adopting it for his Southern Uranometria. To secure consistency between the estimations of magnitude by the different observers and the practical adoption of Argelander's scale, and its extension to stars of the seventh magnitude, Dr. Gould selected, from the *Uranometria Nova*, 1800 stars between the parallels of 5° and 15° North Declination which culminated at nearly the same altitudes at Bonn and at Cordoba. The magnitudes of these stars were estimated by all the four observers to whom the work at Cordoba was to be entrusted, and the results obtained were carefully compared with the magnitudes of the *Uranometria Nova* and, I presume, in cases of discordances reconsidered. It was found that the estimations of the four observers were in perfect accord, to tenths of a magnitude, in the case of 722 of these stars; in the other cases the discordances did not usually exceed the tenth of a magnitude and never exceeded two-tenths, except in cases where there were peculiarities of colour or the presence of some companion star to disturb the estimations. Dr. Gould determined to adopt as his standards of magnitude only those stars upon which the agreement of the four observers was perfect.

But to facilitate the comparisons of the Southern stars with these standards, stars in two regions south of Declination 55° were selected and carefully compared by all the four observers with the standards in the principal type-belt, and thus a secondary set of standards, more conveniently situated for direct

comparison with the Southern stars, was established. The work was then distributed among the four observers, and appears to have been completed about the end of the year 1873.

It will give some indication of the magnitude of the work when I mention that the number of estimations made for the formation of the *Uranometria Argentina* exceeded 46,000.

These estimations of stellar magnitude must be considered as the corpus of the work for which your Medal has been awarded, but Dr. Gould has carefully discussed the results, and compared them with nearly all the materials which were available for the purpose, and, in particular, he has compared his estimations of the magnitude of the brighter stars with results obtained from a discussion of the photometric observations of the second Herschel and of Seidel. The results of this comparison are generally satisfactory, although there appear some slight indications of a change of scale within the range of the four magnitudes compared with Herschel's measures.

The comparison of the Cordoba magnitudes with those of Lacaille, Herschel, and other astronomers, has revealed some cases of marked discordance; but as Dr. Gould has had the great advantage of having his predecessors' work before him, and has been able to refer to the stars themselves for verification and, if need be, correction of his results, it is not probable that these discordances can be due to accidental errors in the Cordoba estimations. In the Notes appended to the Catalogue such cases are carefully pointed out, and discussed whenever sufficient materials existed for the purpose. These Notes will be of great value to our Southern astronomers, and are certain to lead to successful investigation in the interesting field of stellar variation.

The maps published by Dr. Gould are fourteen in number, one of which is a skeleton map showing the proposed revision of the Southern boundaries of the constellations. Each map has been directly compared with the portion of the sky to which it refers before publication, and the greatest care has been taken to reproduce, as closely as possible, the gradations of light over the region of the Milky Way. The position of the Northern Pole of the Galactic Circle is fixed by Dr. Gould at R.A. $12^h\ 41^m\ 20^s$, Decl. North $27°\ 21'$ for the epoch 1875·0. The maps are beautifully executed, and will well repay examination.

The materials collected by Dr. Gould on the Uranometria of the Southern heavens are far more complete and accurate than any which previously existed, and he has, therefore, been naturally led to discuss their bearing on those great questions of the constitution of our stellar universe which offer so fascinating and inexhaustible a field for philosophical speculation.

The results which Dr. Gould has obtained are in general accordance with those of previous investigators on the subject. It appears to be clearly proved that distance is one of the most important factors in producing differences of apparent bright-

ness in the stars; but the agreement between the number of stars of different magnitudes and the number which might be expected if these changes of apparent brightness depended solely on distance is not perfect over any large range of magnitudes. There appears to be a decided preponderance in the number of the brighter stars. It is possible that this preponderance may be partially due to the conventional scale of magnitudes not being a truly photometric scale; and it is necessary, before any close agreement can be expected between the number of stars of the different magnitudes and those computed on the assumption of distance being the sole factor of variation, that the number of stars in a group should be sufficiently great to insure that the mean intrinsic brightness of the stars of each group should be constant, a condition which can only be secured when a considerable number of stars are included in each group, for there are certainly proved variations of intrinsic brightness amongst the stars in a higher proportion than 300 : 1. But, although Dr. Gould had these possible sources of error before his mind, he has been led, after a careful discussion of his own observations, to infer that the preponderance of the brighter stars is due to the existence of a stellar cluster consisting of some four or five hundred stars, of which our own system is supposed to be a member. The position of the northern pole of the medial plane of this belt of stars has been fixed by Dr. Gould at R.A. $11^h\ 25^m$, N.P.D. 60°, whilst that of the Galactic Circle is at R.A. $12^h\ 41^m$, N.P.D. 62° 39′. That there is a striking crowding of bright stars towards the portion of the heavens to which Dr. Gould calls attention is an undoubted fact, and one which had previously attracted notice. It is also proved by Dr. Gould that the number of stars of the different magnitudes, which remain after the abstraction of the stars of this supposed group, agrees more closely than before with the computed number on the assumption that the changes in brightness depend solely on distance. But whether these facts are sufficient to prove our power of discriminating between the stars of this belt, and that general condensation of matter which gives rise to the appearance of the Milky Way is a point upon which I can form no very positive opinion. I think, however, that the values of annual parallax and of relative brightness, which have been found for some of the stars of this belt show that, if it exists as an isolated cluster, it is one of vast extent and great complexity. Looking out from this mere speck of an Earth on the space which surrounds me, and recognising, as I must, the awful and almost inconceivable distances that separate me from the nearest of the stars, compelled to acknowledge that every one of these twinkling points is as much an independent source of light and heat as our own Sun, that every increase of optical power brings a large proportionate number of other stars into view, and in entire ignorance of the position of my point of view amongst these stars, I feel my inability to firmly grasp the geometrical, much less the

physical, constitution of such an universe. I cannot conceive space without limits, or the possible nature of a boundary of such space. However much, therefore, my mind may revel for a time and rejoice in its almost unfettered liberty amid such speculations, yet it finds no Mount Ararat upon which to rest the sole of its foot, and it soon gladly returns to the ark of experiment and observation upon which the foundations of our science have been laid, and the superstructure, if slowly, yet securely raised.

Although, therefore, from the constitution of my mind, and training, I am perhaps unable to do full justice to this, the speculative part of Dr. Gould's work, I can speak with the greatest confidence of the value of the observational results contained in the *Uranometria Argentina*. It is a work of very considerable extent; it has been planned with great care; and executed with the most scrupulous attention to details. It will remain an enduring record of the relative brightness of the Southern stars for its epoch; and will be accepted for many years as the chief authority upon questions of their magnitude; and it is certain, from its very success, to incite other astronomers to efforts in the same direction—efforts which must ultimately lead to its being replaced by something more extensive, something even yet more accurate.

No higher praise can, I believe, be given to work of the class. In our science, at least, men do rise "on stepping-stones of their dead selves to higher things." I am certain that the award of this Medal by your Council to Dr. Gould will be received with the greatest satisfaction by the Fellows of this Society, and by practical astronomers of all nationalities, as a fitting tribute to good work done for the advancement of their science.

Earl of Crawford and Balcarres.

My Lord,

Will you forward, through the representative of the Argentine Republic, this Gold Medal to Dr. Benjamin Apthorp Gould, with the assurance of our high appreciation of the skill, energy, and success, with which he has directed the work of the Cordoba Observatory, and our hopes that his efforts for the advancement of our science may be long continued and equally successful in the future?

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir G. B. Airy, K.C.B., M.A., LL.D., D.C.L., F.R.S.
W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
J. R. Hind, Esq., LL.D., F.R.S., Superintendent of the *Nautical Almanac.*

Treasurer.

Francis Barrow, Esq., M.A.

Secretaries.

J. W. L. Glaisher, Esq., M.A., F.R.S.
E. B. Knobel, Esq.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

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Arthur Cayley, Esq., M.A., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
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A. M. W. Downing, Esq., M.A.
Edwin Dunkin, Esq., F.R.S.
George Knott, Esq., LL.B.
Rev. Charles Pritchard, M.A., D.D., F.R.S., Savilian Professor of Astronomy, Oxford.
A. Cowper Ranyard, Esq., M.A.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. MARCH 9, 1883. No. 5.

E. J. STONE, M.A., F.R.S., President, in the Chair.

The Rev. Edward Aurelius Adams, M.A., Vicar of St. John's, Eastbourne;

Major James Fellowes, R.E., Ordnance Survey Office, Southampton; and

Gerard Brown Finch, M.A., 24 Old Buildings, Lincoln's Inn;

were balloted for and duly elected Fellows of the Society.

Note on a Photograph of the Great Nebula in Orion and some new Stars near θ Orionis. By A. Ainslie Common.

The photograph which I have the honour to present to the Society this evening is a carbon enlargement of a negative taken on January 30, 1883, with the three-foot Reflector, the exposure being thirty-seven minutes.

This photograph shows a marked advance on those I have previously shown at meetings of this Society; and although some of the finer details are lost in the enlargement, sufficient remains to show that we are approaching a time when photography will give us the means of recording in its own inimitable way the shape of a nebula and the relative brightness of the different parts, in a better manner than the most careful hand-drawings.

To find if there is any change of form or relative brightness observable in a nebula with any degree of certainty, it will be necessary to compare photographs taken at some undetermined interval of time; and the best thing to do now seems to me to be to get as many photographs as possible, to form the basis of

comparison with those taken at some future time; and this I am now doing.

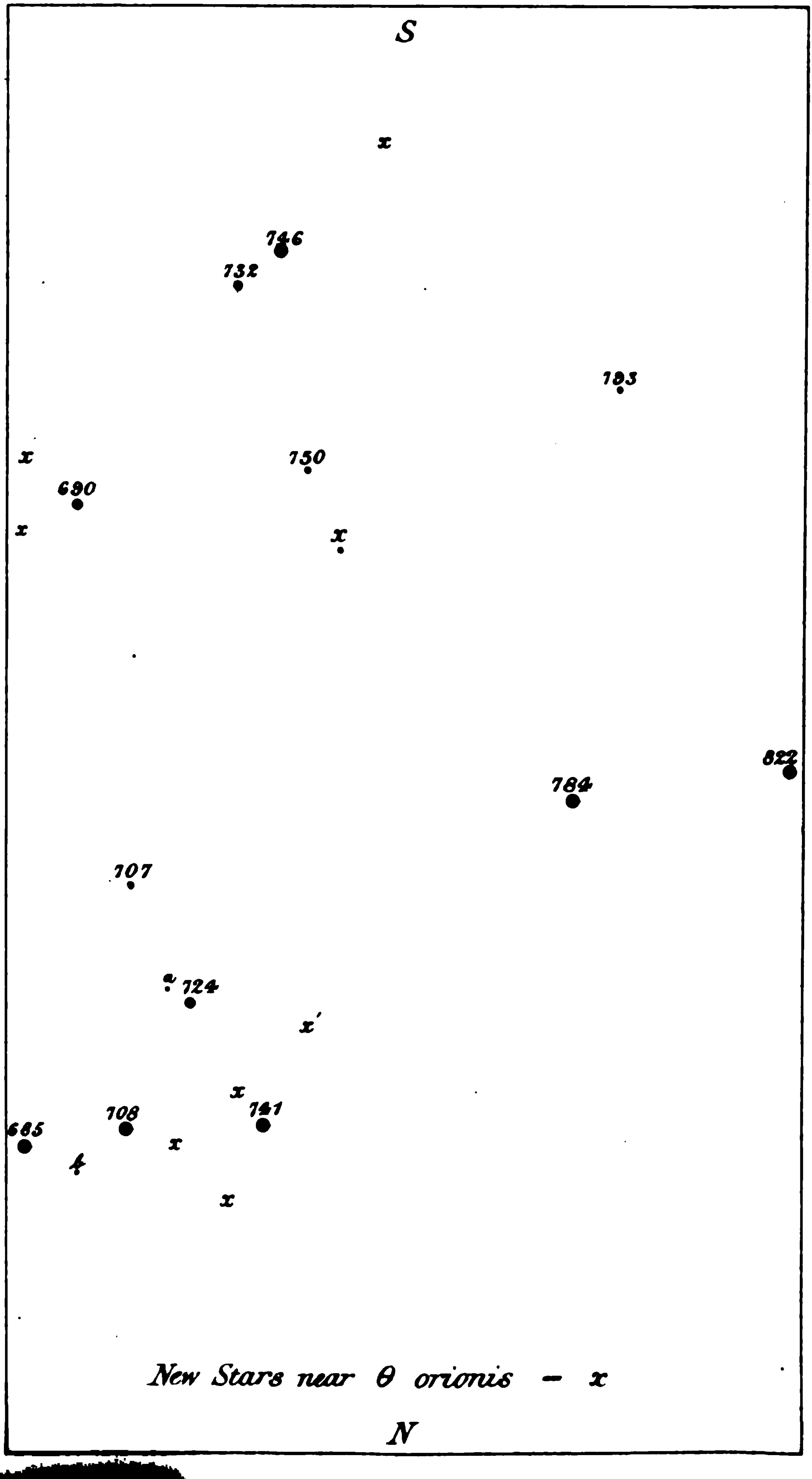
Whilst a comparison of such a photograph as this now shown with any existing drawing can give no reliable evidence of any change having taken place, whatever the observable difference between them may be—for reasons that are very obvious on an inspection and comparison of drawings one with the other—it is very interesting to compare some of the best drawings with the photograph, if only to note the remarkable care that must have been taken in their production.

In making this comparison, the first thing that strikes one is the great difference in the relative intensity of the light of the different parts. This seems to have been the great difficulty always, and from the nature of the object, and the impossibility of having it all in view at once, such a result might be expected. The next thing is the presence of so many long streaks of light of pretty uniform intensity in some drawings, and the general representation of masses of light as rounded or gradually shading off, the photograph showing these as collections of cloudy masses of a knotty or curdled appearance—in this agreeing so well with the eye-view when a powerful telescope is used.

The light of this nebula is so different in intensity that for a proper exposure of the outer portions the central part is much over-exposed; it is therefore necessary to take photographs with different exposures. Thus an exposure of from one to three minutes gives the brighter portions of the central parts in such a way that they can be easily compared and their order noted; longer exposures giving portions less bright in a similar way, till, with a maximum exposure, the very faintest portions can be compared and noted in order. The stars in the nebula can be treated in the same way, the same photographs being available.

This photograph shows some of the fainter portions of the nebula; the most noticeable being (1) the faint crescents of light north of and between the stars 335 and 387 (Bond's numbers are used throughout); these crescents of light, as far as I am aware, are only shown in the beautiful drawing of Lord Rosse, published in the *Philosophical Transactions* for 1868; (2) the dark spaces near and south of the star 479 and the dark space near 570; (3) the peculiar extension of the *proboscis major* at its extremity when it suddenly curves away from the star 793; (4) the nebulous spur (particularly noticed by Sir J. Herschel at the Cape) starting from the star 746 and almost joining the *proboscis major* where it curves away, as already mentioned, as if to make room for it; (5) the large mass of faintish light *p*, the *proboscis major*, and running about parallel with it for some considerable distance from the star 784 up to and beyond the star 793.

There are many other interesting points, about which I hope to have more to say when sufficient materials accumulate for



New Stars near θ orionis — x

profitable discussion. It is well known that many of the stars in and about the nebula are variable, particularly the faint ones, but I was not prepared to find that one of the brighter stars is remarkably variable, though what its period is I have not yet found.

On looking over the negatives taken during this winter I find that the star 822, mag. 10·7, was on January 5, according to several negatives taken that night, fainter than 707, a star of 11·2 mag. December photographs show it brighter than 784, and much brighter than 707. On January 13 it was again a little brighter than either; on January 26, 784 (mag. 10·8), and 822 are shown as equal; on subsequent photographs it appears brighter, March 4 photograph showing it much the brightest, quite equalling 724, a 10·5 mag. star. This is the only case noted, it being too apparent to be overlooked.

With regard to the fainter stars, Professor Holden in his "Monograph of the Central Parts of the Nebula in *Orion*," on p. 184, speaking of faint stars, says—"It will be interesting to know if other large telescopes show stars fainter than 675, my 1, 2, 3, or Lassell's *b*." On January 27, it being too windy to photograph, I looked carefully over the sub-nebulous region and at once found three stars surrounding 741—two near 690, one near 750—and one *sp*. 746. A sketch of the positions of these stars is given here, the new stars being marked by an *x* and the old stars by Bond's numbers. These stars have been seen again on February 3, when another, *sf*. 741, was added; this is marked *x*′. On looking on this night at other parts of the nebula other faint stars were found, as might be expected. Amongst these may be mentioned a star in the *nebula oblongata*, about 150″ *p*. 848, and on the *s* border of this *nebula*. This is, no doubt, the star marked *x* in the plate given by Sir John Herschel at the end of the second volume of the *Memoirs* of this Society, and referred to by him in the *Cape Observations*, p. 30, where he expresses himself as satisfied it does not exist. Professor Holden's star 1 was seen, but not 2 or 3, while two stars are noted as visible, *np*. 652. Lassell's *a* and *b* have always been seen easily, as well as 675, the latter appearing to me to be quite outside the bright edge of the *frons*.

Of these faint stars I find on this and other photographs that Lassell's *a* and *b* are shown, as well as the two stars near 690, the star near 750, the star *sp*. 746, and the star *sp*. 741. As these stars appear on negatives taken with exposures of from 37 to 60 minutes, and the time of exposure can be easily extended to hours, it may be, and I think is, quite possible to get stars invisible to the eye in the same telescope used for photography.

1883. *March* 9.

Notes upon certain Doubtful Star-Places. By Professor Truman Henry Safford.

In compiling a star-catalogue which is to possess great precision at the present epoch, it is often found that the proper motion is at fault. So that if we test the position for some past epoch, we find it very accurate; most accurate for the mean epoch according to weights of the original observations; and nearly as precise for the mean epoch according to weights of the modern observations employed: for the best class of compiled catalogues this epoch will be about 1865, or a few years earlier or later.

The difficulty of obtaining precise proper motions is now but small for Bradley's stars, if they were observed four or five times in each coordinate by himself, and is much greater, in Right Ascension at least, for those stars which were first observed by Piazzi, Lalande, or Groombridge, unless, indeed, they happen to be contained in those more precise catalogues which we owe to Struve, Bessel, or Argelander, a few years later.

For Piazzi and Groombridge were in the habit of adjusting their Transit instruments to a mark, and these adjustments were not often enough repeated for security. Moreover, I have noticed with portable instruments that a reaction sometimes takes place after an adjustment, owing perhaps to the state of molecular strain which the movement of a stiff adjusting screw, little used, may cause in the instruments; so that the parts are quite liable to spring some hours after the exact adjustment has been effected. Be this as it may, it is certain that Piazzi's Transit and even Pond's were frequently several seconds of arc out of the meridian; so that it is not to be wondered at if proper motions derived from these astronomers' catalogues are in error.

In volume iv. of the *Annals* of Harvard College Observatory will be found a catalogue of Right Ascensions, including many close polars, which was planned by myself with a view to establishing a standard secondary catalogue for 1865. I have now in hand, with the Repsold Meridian Circle (just commencing its work) of this Observatory, a similar catalogue, a small portion of which has been sent to press; and the intention of the first portion of this catalogue is to enable me to discuss these close polars more fully, in order to get a better basis for the observations in Right Ascension of the early part of this century. Very fortunately there are observations about 1815 by W. Struve, partly reduced, which will enable us to discuss Piazzi's and Groombridge's Right Ascensions with more thoroughness, provided we have good modern determinations for the sake of the proper motions. Of course Auwers's Bradley furnishes us with an admirable series of Right Ascensions for 1755; but many of Groombridge's stars, observed also by Struve, are not contained in that work.

Another aim of my present work is to revise and clear up a good many discrepancies which I have found from time to time in the catalogues. In some cases new observations are needed for this purpose: in many others it seems only necessary to bring together data already accumulated, and show whence discrepancies have arisen.

The set which I shall notice in this paper includes twelve stars from the fundamental catalogue compiled by Professor Auwers in Publication XIV. of the Astronomische Gesellschaft; these twelve are noted by Prof. W. A. Rogers as discordant in Right Ascension from his own observations in a paper contained in vol. x. of the *Memoirs* of the American Academy, pages 389 to 428; this paper will be cited as R., and the fundamental catalogue as A.

The 12 stars are

1. Bradley 6,	7. η Draconis,
2. η Cassiopeiæ,	8. Groombridge 2377,
3. 36 Camelopardi,	9. β Lyræ,
4. 1 H. Draconis,	10. Groombridge 2900,
5. Groombridge 2164,	11. υ Pegasi,
6. θ Draconis,	

and the star *b Draconis*; for which Prof. Rogers gives no details in this paper, except on page 412.

By referring to volumes x. and xii. of the Harvard Observatory *Annals*, we find Prof. Auwers has already included all these observations of *b Draconis* in his catalogue; and that the discrepancy did not seem to him to warrant either the exclusion of any observations or any further remark.

Of the remaining eleven stars, Nos. 2, 9, and 11 have been well observed by Bradley, and their proper motions are quite certain. No. 2 is double, and has a pretty large annual proper motion. It was also observed by Prof. Rogers for the most part within about a minute of a preceding star—ζ *Andromedæ*. Under these circumstances there is no great singularity in the difference

$$\text{A} - \text{R} = -0\overset{s}{\cdot}090 \text{ (12 observations)};$$

especially as the fifteen observations made at Cambridge between 1863 and 1865 give

$$\text{A} - \text{Annals, vol. iv.} = +0\overset{s}{\cdot}032,$$

or with systematic correction according to Prof. Rogers

$$\text{A} - \text{Annals, vol. iv.} = -0\overset{s}{\cdot}024;$$

whether we consider these discrepancies as due to personal equation, orbital motion, or too great hurry in observation.

Nos. 9 and 11 are discrepant from A. because of errors of computation. The Right Ascensions for 1875·0 in Prof. Rogers's catalogue in volume xii. of the *Annals* should be

$$18^{h}\ 45^{m}\ 27^{s}{\cdot}853$$

and

$$23^{h}\ 19^{m}\ 8^{s}{\cdot}520,$$

instead of $27^{s}{\cdot}774$ and $8^{s}{\cdot}400$ respectively; leaving as discrepancies $+0^{s}{\cdot}007$ and $-0^{s}{\cdot}024$, instead of $+0^{s}{\cdot}086$ and $+0^{s}{\cdot}096$.

None of the remaining eight stars were observed in Right Ascension by Bradley; although four were in Declination. Nos. 5, 8, and 10 have been thoroughly investigated by Argelander, with respect to proper motion; and I see no chance of great error in this element. I have therefore brought up the available newer Right Ascensions of these stars—seconds only—with Argelander's proper motions, as corrected by Auwers for the difference of precession-constants, and with Auwers's or Rogers's systematic corrections, slightly modifying the latter (as I do not understand his Table III. in volume xii. of the *Annals*, and its form is unusual in similar discussions), with the following results, in seconds of time (N. denotes number of observations, W. weight):—

	Gr. 2164.			Gr. 2577.			Gr. 2900.		
	A.	N.	W.	A.	N.	W.	A.	N.	W.
	s			s			s		
Greenwich 1861	16·036	3	1	55·720	5	2	—		
Harv. Coll. 1865	16·129	28	3	—			12·972	10	2
Argelander 1866	—			55·744	8	3	—		
Engelmann 1866	—			55·741	8	3	—		
Pulcova 1871 ...	16·068		5	55·724	—	5	12·997	—	5
Greenwich 1872	—			55·705	5	2	12·747	5	2
Harv. Coll. 1872*	16·264	5	2	55·719	5	2	—		
„ 1875†	16·196	5	2	55·637	22	3	13·082	5	2
Mean ...	16·105		11	55·713		18	12·962		11

The final deviations of Harvard College 1875 are respectively

$$-0^{s}{\cdot}091, \qquad +0^{s}{\cdot}076, \qquad -0^{s}{\cdot}120,$$

instead of

$$A-R = -0^{s}{\cdot}087, \qquad +0^{s}{\cdot}093, \quad \text{and} \quad -0^{s}{\cdot}156.$$

* From Auwers.

† With Rogers's systematic correction, as given by himself. This number includes the observations of the preceding line, which are omitted in taking the mean.

Neither set of discrepancies seem excessive, considering the Declinations of the three stars

$$59^{\circ}\!\cdot\!8, \quad 57^{\circ}\!\cdot\!0, \text{ and } 79^{\circ}\!\cdot\!4.$$

Of the remaining five stars, four are in Bradley's catalogue, but not observed in Right Ascension. The proppr motions of these are given by Prof. Auwers as rather insecure; they are not very important as fundamental stars, and I give simply the corrections which the Right Ascension of A. seems to need, from a rough comparison of the available material.

Bradley 6 ...	...	$+0^{s}\!\cdot\!108+0^{s}\!\cdot\!019\ (t-1875)$
36 Camelopardi	...	$+0\cdot050+0\cdot0053\ (t-1875)$
θ Draconis...	...	$-0\cdot037-0\cdot0030\ (t-1875)$
η Draconis	...	$-0\ 076-0\cdot0060\ (t-1875)$

These diminish Prof. Rogers's discrepancies from

$$-0^{s}\!\cdot\!170;\ -0^{s}\!\cdot\!100;\ +0^{s}\!\cdot\!093;\ +0^{s}\!\cdot\!141,$$

to

$$-0^{s}\!\cdot\!055;\ -0^{s}\!\cdot\!049;\ +0^{s}\!\cdot\!059;\ +0^{s}\!\cdot\!072;$$

leaving nothing greater than $0^{s}\!\cdot\!034 \sec \delta$. The largest discrepancy of all, Groombridge 2164, when reduced to the equator is

$$0^{s}\!\cdot\!046 \sec \delta.$$

As the probable error of one Right Ascension in the catalogue of volume xii. is given as

$$\pm 0^{s}\!\cdot\!013 \sec \delta,$$

there is nothing very remarkable in the amount of the final difference.

The last star, 1 *Draconis* H, is an important polar. Its magnitude is 4·3; it is within $8^{\circ}\!\cdot\!2$ of the north pole, and in a region (9^{h}) of A.R. where other good polars are few; but the observations early in this century are not very accordant. The following five values have been assigned to its annual proper motion by as many astronomers; in each case from a full discussion (probably by least squares) of all available material up to about 1860 or later.

Gould ...	...	$-0^{s}\!\cdot\!0077$
Safford ...	...	$+0\cdot005$
Wagner ...	...	$0\cdot000$
Albrecht ...	...	$-0\cdot018$
Auwers ...	...	$-0\ 0174$

The cause of these differences lies, probably, in the different weights given to Groombridge, and perhaps Piazzi, or the retention or exclusion of one of them. The mean of all these values, $-0^s{\cdot}0076$, agrees nearest with Dr. Gould's, which I shall retain; with this, the following are the Right Ascensions from the authorities of Publication XIV. and some later:—

	A.	N.	W.
	h m s		
Pulcova 1846·9 ...	9 19 5·90	49	4
Washington 1863·5 ...	5·80	13	2
Greenwich 1864·2 ...	5·86	6	2
Harvard Coll. 1864·5	6·02	38	3
Pulcova 1865... ...	5·90	—	7
Greenwich 1870·7 ...	5·65	7	2
Harvard Coll. 1872·9	5·95	28	3
Berlin 1874·8 ...	5·99	18	3
Williamstown 1882·8	5·98	7	2
Mean	9 19 5·906 ± 0s·022		28

This probable error holds good for 1867; the correction to A. will be—

$$+0^s{\cdot}166+0^s{\cdot}0097\ (t-1875).$$

The Williamstown observations were made for the purpose of obtaining the instrumental corrections, and were reduced by neighbouring polars from A.; the instrument was the Repsold Meridian Circle of this Observatory.

It is much to be desired that this star should be pretty thoroughly observed; I have among my note-books a result of observations at Montsouris, which give for 1875

$$9^h\ 19^m\ 5^s{\cdot}71 \text{ (70 observations)},$$

but have not the original at hand to refer to; including it with a weight=3, we should have as final result for 1875·0

$$9^h\ 19^m\ 5^s{\cdot}887 \pm 0^s{\cdot}023.$$

Williamstown, Mass.:
1883, *Feb.* 21.

On the Relative Motion of the Components of 6 *p Eridani.* By A. M. W. Downing, M.A.

In his recently-published *Double-Star Results*, 1871–1881—a valuable contribution to our knowledge of a hitherto too much neglected department of southern astronomy—Mr. Russell has inserted a note on the southern double star 6 or *p Eridani*, to the effect that the hypothesis that the relative motion of the components is rectilinear and not orbital accords better with all the observations made since Herschel's time, and that therefore, if subsequent observations confirm this result, we must conclude that this star is no longer to be reckoned amongst the known binary systems.

As the point thus raised by Mr. Russell is one of considerable interest, I have thought that it would be worth while to discuss analytically all the available observations (including those made at Sydney) of this star, in order to see if it would be possible to decide between the rival hypotheses. And, as Dr. Doberck has published elements of the star in which the Sydney observations have not been included, it will be possible to see what is the effect of the later observations in modifying these elements.

Dr. Doberck's elements are (*Ast. Nach.* No. 2148)—

$$
\begin{aligned}
P &= 117{\cdot}51 \text{ years} \\
T &= 1817{\cdot}51 \\
e &= 0{\cdot}378 \\
\Omega &= 81^\circ 42' \\
\lambda &= 327 \;\; 15 \\
\gamma &= 44 \;\; 40 \\
a &= 3''{\cdot}82
\end{aligned}
$$

This double star was first measured by Dunlop in 1825, secondly by Herschel in 1835. Mr. Russell states that neither of these observations accord with the hypothesis that the motion is in a straight line, but that Herschel's *angle* is nearly correct, his distance being a little too small. Dunlop's observation does not agree with the place computed from Dr. Doberck's elements for that epoch, and is probably quite inaccurate, I have therefore made no use of it in deducing new elements, but I have not felt at liberty to reject Herschel's observation, especially as the angle only is used in determining all the elements with the exception of the semi-axis major. (It will be seen that Herschel's observed distance has not been used in determining this latter element.) I have accordingly formed the following six normal angles from the observations by combining them in convenient groups (the angles being reckoned from the circle of declination passing through the principal star at the epoch 1870·0).

	Epoch.	Position-Angle.
I.	1835·03	$302^\circ.44$
II.	1846·12	276·35
III.	1851·83	266·69
IV.	1858·36	257·58
V.	1870·92	242·08
VI.	1878·68	236·38.

It was evident that Dr. Doberck's period would have to be considerably increased to represent these normal places, and it was found by trial that the following values would nearly represent the observed angles—viz. $P = 235{\cdot}02$ years, $T = 1810{\cdot}98$, and $e = 0{\cdot}4$. From these were computed true anomalies corresponding to each epoch, and hence (using Dr. Doberck's values of ☊, λ and γ) the corresponding position-angles were found. Then by varying successively λ and γ each 1° the differential coefficients of θ (position-angle) with respect to each of these elements were determined, $\frac{d\theta}{d☊}$ being of course unity; and by comparing the computed and normal position-angles six equations of condition were formed to determine the corrections to ☊, λ and γ. These being solved by the method of least squares, the new values were ☊ $= 47^\circ\ 22'$, $\lambda = 330^\circ\ 22'$, and $\gamma = 25^\circ\ 56'$. From these new values were then found true anomalies corresponding to each normal epoch; and from these, with values of the eccentricity $e = 0{\cdot}4$ and $e = 0{\cdot}5$, two sets of mean anomalies were computed; and from the errors of these a corrected value of e was found by interpolation, and hence corrected values of P and T were deduced. The values of ☊, λ and γ were again corrected in the manner described above; and finally a was found from all the measures of distance (excluding Dunlop's and Herschel's) in combination with the new values of the other elements.

The elements are then as follows—

$$
\begin{aligned}
P &= 224{\cdot}57 \text{ years} \\
T &= 1814{\cdot}43 \\
e &= 0{\cdot}4127 \\
☊ &= 48^\circ\ 0' \ (1870{\cdot}0) \\
\lambda &= 329\ \ 52 \\
\gamma &= 26\ \ \ 5 \\
a &= 4''{\cdot}75
\end{aligned}
$$

As these elements very fairly represent all the measures except Dunlop's angle (as will be seen from the detailed comparison with observation, given below), they were adopted, as being sufficiently accurate for the present purpose.

We have now to proceed on the assumption that the motion

of the *comes* is uniformly in a straight line—of course excluding Dunlop's and Herschel's measures, as they are manifestly inconsistent with this hypothesis.

Using, then, the last five of the normal position-angles given above, with corresponding values of the observed distances, the equation to the "most probable" right line passing through these five points is—

$$4{\cdot}163 = \rho \cos(\theta - 282^\circ\ 1');$$

and the epoch of nearest approach of the components on the assumption of rectilinear motion being 1842·62, the distance (ρ) and position-angle (θ) at any time t are found from this equation in combination with—

$$0{\cdot}1205\ (1842{\cdot}62 - t) = 4{\cdot}163 \tan(\theta - 282^\circ\ 1').$$

The following table contains the comparison with the individual annual results, the discordances under (I.) being those resulting from the assumption of elliptic motion, and those under (II.) from the assumption of rectilinear motion :—

Epoch.	Observer.	θ_o	$\theta_o - \theta_c$ (I.)	$\theta_o - \theta_c$ (II.)	ρ_o	$\rho_o - \rho_c$ (I.)	$\rho_o - \rho_c$ (II.)
1825·96	Dunlop	343°·1	+9°·8	+35°·5	2″·5	−0″·27	−2″·12
35·03	Herschel	302·3	−0·3	+8·0	3·65	+0·46	−0·61
45·88	Jacob	276·0	−0·8	−0·5	4·16	+0·24	−0·02
46·35	„	276·5	+0·5	+0·5	4·32	+0·36	+0·13
49·82	„	270·0	+0·2	−0·2		—	
50·80	„	268·7	+0·5	+0·1		—	
51·79	„	266·4	−0·1	+0·3	4·30	−0·03	−0·01
52·76	„	264·8	−0·2	−0·8	4·14	−0·25	−0·20
53·96	Powell	263·2	0·0	−0·6		—	
56·09	Jacob	261·1	+0·5	+0·4	4·70	+0·07	+0·23
57·96	„	258·1	+0·3	0·0	4·49	−0·24	−0·07
61·03	Powell	253·4	−0·3	−0·6	4·86	−0·03	+0·14
70·92	Russell	242·1	−1·0	−0·6	5·46	+0·02	+0·08
77·03	Ellery	237·3	0·0	+0·1	5·0	−0·73	−0·88
78·34	Russell	236·7	+0·6	+0·5	6·09	+0·30	+0·10
79·93	Hargrave	237·3	+2·6	+2·4	5·44	−0·40	−0·69
1880·44	Russell	234·7	+0·4	+0·2	6·30	+0·43	+0·13

In this table θ_o and ρ_o are the observed, θ_c and ρ_c the computed, position-angles and distances respectively; the computed position-angles being corrected for the effect of precession. It appears from this comparison that the hypothesis of orbital motion represents the whole series of observations fairly well, whilst that of relative rectilinear motion does not; and that

even confining ourselves to measures made subsequent to Herschel's observation, the discordances from the first assumption are on the whole no larger than those from the second. It would appear from this, therefore, that, as far as can be judged from the observations as yet published, there is not sufficient evidence to justify us in asserting that *p Eridani* is other than a binary star. It is to be hoped that observers in the southern hemisphere will not lose sight of this interesting double star, but will continue to measure it from time to time.

With regard to the proper motions of the components, it appears from a comparison of their places in the Cape Catalogue for 1840 with those in the Cape Catalogue for 1880 that they have a common proper motion of $+0^{s}\cdot03$ in Right Ascension; whilst in North Polar Distance that of the preceding star (the *comes*) is $+0''\cdot07$, and that of the principal star $-0''\cdot08$. These latter values would support the hypothesis of the *comes* moving relatively in a straight line towards the south, but unfortunately the N.P.D. of the following star in the Cape Catalogue for 1840 depends on a single observation, and therefore no reliance can be placed on the proper motion deduced from it.

Blackheath:
1883, *March* 8.

Notes on some of Schjellerup's Identifications of Al-Sufi's Stars. By J. E. Gore, M.R.I.A.

Some years since M. Schjellerup, the well-known astronomer, published a French translation of two Arabic manuscripts containing a description of the heavens written in the tenth century by the Persian astronomer Al-Sufi. Schjellerup's translation is entitled *Description des Etoiles Fixes, composée au milieu du dixième siècle de notre ère par l'astronome Persan, Abd-al-Rahman Al-Sufi* (St. Pétersbourg, 1874). Schjellerup gives a synopsis of the stars observed by Al-Sufi, identifying Al-Sufi's stars with those at present recognised by Greek and Roman letters, and also giving the magnitude of each star as estimated by Ptolemy, Al-Sufi, and Argelander. I have carefully gone through all Al-Sufi's descriptions of each constellation, comparing his account of the position of each star with the stars as shown in the atlases of Behrmann, Heis and Proctor, and find that in the great majority of cases Schjellerup's identifications are very correct. There are, however, a good many cases in which I cannot agree with Schjellerup with reference to the star described by Al-Sufi. In the Harvard College *Annals*, vol. ix. p. 48, Peirce gives several cases in which he disagrees with Schjellerup, and to these I have added several others. The following are all the cases in which I differ with Schjellerup:—

Hercules.—Two stars mentioned by Al-Sufi amongst the "externes" of this constellation (page 73) as following

θ *Herculis* are not identified by Schjellerup. They seem to me to be 195, or 199 Heis *Draconis* and κ *Lyræ*. This view seems strengthened by the fact that Al-Sufi in his description of the constellation *Lyra* makes no mention of κ *Lyræ*, so that probably he included it in *Hercules*.

Cassiopeia (page 83).—Peirce is quite right about the 9th star, which is evidently ϕ, and not θ, as Schjellerup gives. For the 8th star Schjellerup gives μ. I prefer θ, however, as Al-Sufi's description applies equally well to it, and as it is brighter than μ, it was probably the star observed by Al-Sufi. It seems improbable that of two stars close together (like μ and θ) Al-Sufi should have recorded the fainter star and omitted the brighter.

Equuleus (page 111).—In the synopsis Schjellerup does not attempt to identify the 4 stars described by Al-Sufi in this constellation; but from Al-Sufi's description they are evidently: $1=\alpha$; $2=\beta$; $3=\gamma$ and $4=\delta$ *Equulei*.

Aries, 5th star.—Al-Sufi's description would seem to apply better to 4 Fl than to ι, as Schjellerup gives. Al-Sufi says (p. 125): "La 5e se trouve au sud de la 1re (γ), qu'elle précède vers l'occident, étant située sur le cou." This applies to 4, but not to ι, which *follows* and not *precedes* γ. This identification would, however, imply an error of about 2° in the longitude of Ptolemy's star, so that probably Schjellerup's identification is correct.

Taurus (p. 132). Schjellerup does not identify the stars Nos. 29, 30, 31 and 32 of Al-Sufi, but it is evident from Al-Sufi's description that they are the four brightest stars in the *Pleiades*, 32 being probably η (*Alcyone*). In fact, Al-Sufi says with reference to these stars:—"Il est vrai que les étoiles des *Pleiades* surpassent bien les quatre mentionnées ci-dessus, mais je me borne à ces mêmes quatre, parce qu'elles sont très près l'une de l'autre et les plus grandes; c'est pourquoi nous les avons mentionnées en négligeant les autres."

I agree with Peirce's remarks about star No. 6 of the "externes."

Al-Sufi describes (p. 134) a star to the south of the 11th star (γ *Tauri*) which Schjellerup does not identify. This star seems to be either 79 (b) *Tauri* or 83 *Tauri*. I prefer 79, as it is slightly the brighter. Al-Sufi says: "Ces trois étoiles font une ligne parallèle à la ligne boréale de la figure du *dal*" (γ, δ and ϵ *Tauri*). This applies exactly to σ, ρ and Fl 79.

Virgo, 18th star.—From Al-Sufi's description, this is very evidently Fl 82 (m) *Virginis*, and not Lalande 25396, as given by Schjellerup in his synopsis. Al-Sufi says (p. 160): "La 18e suit la 17e [76 Fl]; c'est la plus boréale des deux qui se trouvent dans le côté postérieur du quadrilatère, et forme avec l'obscure 17e et *al-simâk* [*Spica*] une ligne à peu près droite; entre elle et la 17e, il y a un peu plus d'une coudée. Ptolémée la dit des moindres de la quatrième grandeur, mais en vérité elle est des moindres de la cinquième. Avec la 16e [74 Fl] et *el-*

simâk elle forme un triangle, *al-simâk* étant au sommet; les deux autres à la base, et la 17^{e} dans le côté méridional du triangle. Entre la 16^{e} et la 18^{e}, il y a moins de deux coudées." All this applies very well to 82 (*m*) *Virginis*, but not at all to Lalande 25396.

Schjellerup identifies the fifth star of the "externes" of *Virgo* with Fl 61 *Virginis*, but it seems to me that the stars 55 and 57 *Virginis* (which are close together) suit Al-Sufi's description better, for he says (p. 161): "La 5^{e} est la suivante; c'est une étoile double de la cinquième grandeur." It must be added, however, that this identification is doubtful, as it would imply a large error in latitude in the place of the star as given by Ptolemy.

Scorpio, 14th and 15th stars (p. 172).—Schjellerup does not identify the 15th star, and identifies the 14th with ζ *Scorpii*. From Al-Sufi's description, however, I believe the 15th star to be ζ and the 14th a nebula closely North of ζ, which I have often observed in the Punjab, India, as a hazy star of about magnitude 4½. This nebula is No. 3652 of Sir John Herschel's catalogue of nebulæ in the *Cape Observations*.

Herschel says: "Place of a double star 5 mag., the *p* but one of 7 bright stars in the middle." The positions of Nos. 14 and 15 given by Ptolemy seem to confirm this view, as he makes the stars differ only 10′ in longitude, but the latitudes differ by 50′, No. 14 being the northern of the two; which agrees with Al-Sufi's description. The stars could not be ζ^1 and ζ^2 *Scorpii*, which have exactly the same Southern Declination.

Schjellerup does not identify No. 1 of the "externes" of *Scorpio*, but it is very evidently the star γ *Telescopii*, which Sir J. Herschel says is in the same field with the nebula 557 *Dunlop*. This nebula is not in Heis' Atlas, but it is marked in Proctor's Atlas, and the star γ *Telescopii* is No. 63 of *Scorpio* in the Catalogue of Behrmann's *Atlas des Südlichen Gestirnten Himmels*, where it is rated 3–4 mag. Lacaille rated it 4 mag. It is No. 7449 of the "Catalogue of 9766 Stars." Al-Sufi says: "Ptolémée la dit nébuleuse."

Sagittarius.—14th star.—Schjellerup says *v*, but this seems to be a misprint for *υ*.

26th and 27th stars of *Sagittarius*.—Schjellerup identifies these with *m* and *e* of Lacaille. I cannot find what these stars are, but Al-Sufi's 26th star is evidently No. 77 Behrmann *Sagittarius*, and his 27th is ι *Sagittarii* (5–4 mag. Behrmann).

Aquarius (p. 188).—Schjellerup does not identify the 27th and 28th stars, but they seem to be ψ^1 and ψ^2 *Aquarii*. He identifies the 29th star (and I think rightly) with ψ^3 *Aquarii*.

There seems to be something wrong about Al-Sufi's description of the stars 31 and 32 of *Aquarius*. If we assume these stars to be ω^1 and ω^2 *Aquarii*, Al-Sufi's description will not apply, for he says, "La 32^{e} est la suivante et la plus boréale des deux," whereas, the more northern of the two is *preceding*, not

following. Possibly Al-Sufi may have observed the variable star R *Aquarii*, when at its maximum, as it lies about the right distance south of ω.

Orion, 6th star.—κ is a misprint for k (74 Fl), which is evidently referred to by Al-Sufi. The 9th star is f_2 (72 Fl), not f_1; and the 10th star is f_1 (69 Fl), not f_2. For Al-Sufi says: "La 9^e^ est la suivante des deux petites contiguës au nord de la 7^e^ (ξ) et la 8^e^ (ν).

30th star (p. 206). Schjellerup makes this v, and Peirce says it is e. I cannot agree with either identification. From Al-Sufi's description the star is c (45) *Orionis*, the northern star in the well-known "sword" of *Orion*. Al-Sufi says: "La 30^e^ est la boréale des trois étoiles rangées et voisines qui se trouvent au-dessous de la 28^e^ [ζ *Orionis*], qui est la suivante des trois situées dans la ceinture, s'inclinant de plus d'une coudée vers le sud." This clearly indicates c. Al-Sufi's 37th star is e (29 Fl).

Eridanus, 8th star.—Schjellerup makes this o^2, but Peirce says he prefers 98 Heis *Eridani*. As, however, the latter star is only of the sixth magnitude, I am inclined to agree with Schjellerup that Al-Sufi intended o^2. Ptolemy's star was probably 98 Heis.

34th star.—I agree with Peirce that Al-Sufi's description of the position of this star points to θ *Eridani*, and not to α. Still Al-Sufi says distinctly: "Elle est de la première grandeur; c'est celle que l'on marque sur l'astrolabe méridionale et que l'on nomme *âchir al nahr*, La Fin du Fleuve." However, Peirce is probably right.

17th star of *Eridanus*.—Schjellerup makes this Lalande 4969, but this identification seems doubtful, as Baily says in his notes to Ulugh Beigh's Catalogue: "This star, which is also in Ptolemy's catalogue, cannot now be found."

Canis Major.—I agree with Peirce in his identifications of the stars Nos. 5, 6, 7, 8, 9, without the figure.

Argo, 2nd star (p. 224).—This is called ρ in Proctor's Atlas. Heis calls it ι (15 Fl), and Behrmann ρ, but both these latter authorities agree that the star is B.A.C. 2728.

9th star.—This seems to be Fl 1 *Argûs*; σ is a star about 15° further south.

11th star.—This seems to be B.A.C. 2484 (5 mag. Heis and Behrmann).

13th, 14th, 15th, and 16th stars.—I agree with Peirce in his identifications of these stars.

18th and 19th stars.—I fail to identify these stars from Al-Sufi's description, which does not apply to any stars in the vicinity of ζ, which is Al-Sufi's 17th star. Schjellerup makes the 18th α, which must be a misprint for a. He does not identify the 19th star.

19th star. Al-Sufi in his description of the position of the 33rd star (p. 227) says: "La ligne droit menée de celle-là à la

brillante 17^e [ζ *Argûs*] passe entre la 18^e et la 19^e, qui sont les deux obscures situées au-dessous de la brillante 17^e." As this remark does not apply to any naked-eye stars in the vicinity of ζ, it would seem possible that Al-Sufi observed two stars which have since disappeared.

The 25th and 26th stars, which Schjellerup does not identify, seem to me to be respectively *a* and *b Velorum* (rated 4–5 by Behrmann). Taking Peirce's identifications of the 23rd and 24th stars as correct (as they seem to be), Al-Sufi's description applies exactly to *a* and *b Velorum*.

With reference to Peirce's remarks about Al-Sufi's stars 28, 29, and 30 of *Argo*, I find that Peirce's stars *a Mali*, *c Mali*, and *d Mali* are identical respectively with o^2, o^3, and o^4 *Navis*, given by Schjellerup; so that Peirce really agrees with Schjellerup.

Hydra, 11th star.—Schjellerup does not identify this star, but from Al-Sufi's description (p. 233) it seems to be 58 Heis *Hydræ* (=3226 B.A.C.). Al-Sufi says: "La 11^e est une petite étoile des moindres de la sixième grandeur; Ptolémée la dit absolument de la sixième. Elle se trouve dans le voisinage et du côté boréal de la brillante [α *Hydræ*] située entre celle-ci et la 10^e [τ' *Hydræ*]."

9th star.—Schjellerup makes this α *Centauri*, but this is evidently a mistake. From Al-Sufi's description the 9th star is plainly 165 Behrmann *Centaurus* (=4759 B.A.C. = 5911 Lacaille).

10th and 11th stars.—Schjellerup calls these *c* and *b Centauri*. They seem to be respectively 175 and 173 Behrmann (5–4 mag.).

19th star.—Schjellerup identifies this with *o*, and does not attempt to identify the 20th star. From Al-Sufi's description the stars 18, 19, and 20 are probably :—18 = ζ (as Schjellerup gives), 19 = υ^2 *Centauri*, and 20 = υ^1 *Centauri*. The magnitudes given by Behrmann for these stars agree well with those of Al-Sufi.

21st star.—Schjellerup does not identify this; but from Al-Sufi's description of the position of this and the 22nd star (ξ) there can, I think, be very little doubt that the object referred to by Al-Sufi is the well-known cluster ω *Centauri*. Al-Sufi's words are: "La 21^e se trouve devant la brillante 18^e [ζ], et est de la cinquième grandeur" [I have seen it in the Punjab like a hazy star of about 4½ mag.]; "elle est située où commence la croupe du cheval et finit le dos humain. Il y a entre elle et la 18^e une distance de deux coudées et demie." This exactly describes the position of ω.

28th star of *Centaurus*.—Schjellerup does not identify this, but it seems to be Behrmann's 125 *Centauri* (5–6 mag.) (= 4580 B.A.C.). Al-Sufi's description applies to this star very fairly.

37th star.—Schjellerup makes this θ *Centauri*, but this is apparently a misprint. The star referred to by Al-Sufi is—according to his very clear description—the star marked *o* in Behrmann's

Atlas. It is No. 84 (*Centaurus*) in the Catalogue, where it is rated 4·5 mag., but has no letter attached to it. Al-Sufi's magnitude is also 4·5. Al-Sufi's 6th star is θ.

Lupus.—With reference to two stars described by Al-Sufi (p. 246) south of α *Lupi*, and which Al-Sufi says are not mentioned by Ptolemy, Schjellerup remarks in a foot-note, "Probablement α_2 and α_1." I cannot find what stars α_1 and α_2 are, but the stars referred to by Al-Sufi are very evidently ρ and σ *Lupi*, rated 5 mag. by Behrmann.

16th and 17th stars.—Schjellerup makes the 16th star λ; but as λ is the 6th star, this cannot be λ. He does not identify the 17th. From what Al-Sufi says, the 16th and 17th stars are very evidently χ and ξ *Lupi* (5–6 mag. Behrmann).

18th and 19th stars.—Schjellerup makes the 18th δ *Lupi*; but δ is the 3rd star. He does not identify the 19th. These stars seem to be 1 and 2 *Lupi* in Proctor's Atlas (30 and 33 Behrmann, *Lupus*).

Corona Australis, 7th star.—Schjellerup makes this κ; but this is evidently wrong. The star is clearly α, for Al-Sufi says, "La 7e se trouve au-dessus et près de la 6e [β] vers le nord."

10th star.—This Schjellerup does not identify, but it is probably 20 Behrmann (= 6444 B.A.C.).

13th star.—Schjellerup calls this ξ; but in Behrmann's Southern Atlas there is no star which exactly suits Al-Sufi's description, the nearest being Behrmann's No. 8. But this is only 1° south of κ, instead of 3° 30′ ("une coudée et demie") as stated by Al-Sufi.

I will conclude with a remark made by Peirce (Harvard *Annals*, vol. ix. p. 51), and which I fully endorse:—"The work which the learning of M. Schjellerup has brought to light is so important that the smallest errors of details become interesting."

The Variability of β Cygni and 63 Cygni.
By the Rev. T. E. Espin, B.A.

It has doubtless escaped Professor Pritchard that the star *β Cygni* has long been suspected of variation. It will be found entered as a suspected variable in *Chambers' Astronomy*, where the authority for its variation is Klein, and in the catalogue of 343 suspected variable stars published in the *English Mechanic* (communication No. III., June 21, 1882), where the authorities are Klein and Webb. A letter of the Rev. Prebendary Webb in the same periodical calls attention to the loss of light of late in this star. *β Cygni* belongs to a class of variable stars which seem quite distinct from the ordinary variables of Class I. and Class II. (*i.e.* stars with periods of less than 80 days and slight variation, and stars with periods above 130 days and great variation). The variation of *β Cygni* is not large—probably less than a magnitude—while the period is one of several years.

A remarkable instance of this class of variable star is No. 140 of the same catalogue, Flamsteed's 63 *Cygni*, R.A. $21^h\ 2^m$ $+47^\circ\ 10'$. In January 1878 it was about 6·0 magnitude. With the exception of a slight fluctuation or two it increased in light till, in November 1881, its magnitude was 4·7. On May 4, 1882, it was as bright, but on August 8 it seemed to have lost light, and on August 11 it was about 5·0 magnitude. On January 15, 1883, it had fallen to 5·6, since which it has increased in light, and is now (February 14, 1883) about 5·1. The comparison stars are:—

5 Ursæ Minoris	4·5
4 "	5·0
59 Cygni	5·3
53 "	5·7

The period from minimum to minimum is thus about five years, and the observed variation max. 4·7± min. 6·0±. If *β Cygni* be a variable of this class the difference between the Harvard and Oxford photometric measures is at once accounted for. It seems impossible to imagine so great an error as half a magnitude in the measures of the former.

West Kirby, Birkenhead:
1883, *Feb.* 15.

Sur l'observation du Passage de Vénus faite à l'Observatoire de Moncalieri. Par F. Denza.

(*Communicated by the Secretaries.*)

J'ai vu dans les *Monthly Notices* de la Société Royale d'Astronomie que ma courte relation sur les observations du passage de *Vénus* faite dans cet Observatoire de Moncalieri a été prise en considération.

Comme la publication de ma relation subit encore quelque retard, et désirant mettre la Commission en état de mieux apprécier la valeur du temps assigné pour le premier contact extérieur, je crois opportun de vous communiquer la circonstance suivante, qui, à mon avis, est importante, afin de vouloir la transmettre à la Commission. Elle est extraite de la Note que j'ai présentée à l'Académie Royale des Sciences de Milan.

"Pendant que je m'appliquais avec la plus grande tension des yeux, à saisir l'instant du contact extérieur, chose fort difficile dans nos conditions, je vis apparaître, un peu avant l'observation du contact extérieur, à peu près une minute et demie ou deux minutes, sur le fond clair du ciel près du Soleil et un peu plus haut que le point fixé (145° du Nord à l'Est), comme une ombre ou une tache noirâtre, sur laquelle je fixai aussitôt mon regard, et que j'observai jusqu'à ce qu'elle s'approchât du Soleil.

"Quand il me sembla que le contour de cette tache touchait le bord du Soleil, ou, pour mieux dire, qu'à peine elle commençait à s'avancer sur ce dernier, le chronomètre marquait

$$\overset{h}{2}\ \overset{m}{49}\ \overset{s}{31{\cdot}0}, \text{ temps moyen de Rome.}$$

"Ce fut là ce que je considérai comme le premier instant du contact extérieur.

"Craignant une illusion, je continuai à y tenir l'œil fixé, mais au bout de 30 secondes environ, l'entaille devenait distincte et certaine, presque un degré plus au Nord que le point établi pour le contact.

"J'attendis encore un peu; et lorsqu'elle fut devenue nettement appréciable, ayant une largeur d'un peu plus de 2″, je marquai l'heure une seconde fois et j'obtins

$$\overset{h}{2}\ \overset{m}{50}\ \overset{s}{29{\cdot}7}."$$

Les temps que je viens d'indiquer sont renfermis dans les limites de quelques secondes, à cause de la refraction et surtout à cause de l'ondulation du contour solaire, produite par l'agitation de l'atmosphère. Pour ces mêmes raisons on eut quelque incertitude pour déterminer l'angle de position correspondant au point du bord du Soleil où le contact devait s'effectuer.

Position géographique de l'Observatoire de Moncalieri.

		°	′	″
Latitude Nord	=	44	59	51·3
Longitude West Rome ...	=	4	46	36·8
		h	m	s
		0	19	7·1

On the Observations of the Transit of Venus, 1882, December 5–6, made at the Lick Observatory, Mount Hamilton, California. By Professor David P. Todd, M.A.

(*Communicated by W. H. M. Christie.*)

I arrived at the Lick Observatory, on the summit of Mount Hamilton, in the evening of November 21. The Horizontal Photoheliograph—the chief instrument of the Observatory to be employed during the Transit—had been, in the main, mounted and got in readiness before my arrival by Mr. Fraser, and a few preliminary photographs had already been taken by Captain Floyd. It remained to complete the unfinished portions of the instrument, to mount and adjust the same, to modify some

details of the instrument which had been constructed wrongly, and to make sure of the convenient and effective working of every part.

Especial attention was given to the accurate determination of the position of the focal plane of the objective, and the method adopted—being nothing short of the critical examination, by many persons independently, of several sets of trial plates exposed at varying distances from the objective—finally indicated the setting of the plate-holder true to the $\frac{1}{8000}$th part of its focal length. Great care was taken to prevent the mishap of fogged plates, from scattered and diffused light falling upon the sensitive film during exposure; likewise to insure the perfect definition of the limbs of the Sun and *Venus*, and to produce an image of the Sun on the photographic plates which should be entirely free from abnormal distortion. The wet process was employed in making all the pictures of the Transit, and the photographic operations were in charge of Mr. Lovell.

The Photoheliograph was mainly constructed by Alvan Clark & Sons, and is essentially like those made for the American Transit of *Venus* Commission. A detailed description of these instruments, with plates, is given in Part I. of the American *Observations of the Transit of Venus of* 1874, by Professor Newcomb. The Lick Photoheliograph, like all the others, has an objective five inches in diameter. Its focal length is almost exactly forty feet, or about $\frac{1}{30}$th part greater than the mean focal length of the eight instruments of the Commission. The diameter of the heliostat mirror—an unsilvered glass disk—is a little greater than seven inches. The objective and the mirror were mounted on two adjacent piers, and the plate-holder on a third pier coming up in the interior of the photographic house. These piers were all set in the meridian of the Transit Instrument, and were laid up of brick, their foundation being in the rock of the mountain summit.

The conditions of weather during the two weeks preceding the day of the Transit were, in general, very favourable for the work of preparation. No snow fell, and on only two days were there any rains—these very slight. Violent winds interfered with our operations on three or four days. The temperature was rarely below 50° and most of the time above 60°. At midnight, November 30, the sky cleared, after three and a half days of continuously cloudy weather. From that time until the afternoon of December 7 we saw no cloud, day nor night, which could interfere in the least with any observation we had to make. Thin cirrus was floating above the summit on the morning of the 2nd, but it had vanished completely within two hours; and on three or four occasions clouds were observed near the horizon, but they never rose. The wind blew in fitful gusts night and day the 3rd and 4th, and the morning of the 5th. But very soon after 12 o'clock that day the winds entirely subsided, and for the next fifty or sixty hours the utmost tranquillity prevailed,

the temperature never falling below 60°, and rising to very near 70° in the shade at noon on the day of the Transit.

The Sun rose about 7 o'clock, December 6, with *Venus* a good way on its disk. The planet was observed by Captain Floyd at intervals throughout the time of the Transit, with the 12-inch Equatorial of the Observatory; and with this instrument he made several drawings, and observed the two contacts at egress. These were observed also by myself with the 4-inch Transit Instrument, mounted on its reversing carriage.

The first photograph of the Transit of *Venus* was taken December 5, $19^h\ 11^m$, local mean time. The exposure was $1\frac{1}{2}^s$ long, and the slit $3^{in}\!\cdot\!0$ wide. Only a very faint image came out on the plate. The fourth exposure, somewhat shorter, and with the slit the same width, gave, at $19^h\ 17^m$, a picture sufficiently intense for measurement; but the vertical diameter was about $\frac{1}{18}$th part, or $\frac{1}{4}$ of an inch, shorter than the horizontal one, and the limb was not well defined. Plate No. 13, at $19^h\ 50^m$, slit $1^{in}\!\cdot\!0$ in width, and exposure $0^s\!\cdot\!4$ long, is the first photograph of real value, though the five immediately preceding it may be worth measuring. The width of the slit was gradually reduced as the altitude of the Sun increased, being successively $0^{in}\!\cdot\!75$, $0^{in}\!\cdot\!5$, and $\frac{3}{8}$ inch, until at $21^h\ 20^m$ it was set at a width of $0^{in}\!\cdot\!25$, and so kept until the end. The exposures were quite uniformly $0^s\!\cdot\!25$ in length.

Thirteen reversals of the plumb-line were made during the period of the exposures. The exposing-slide was moved to the east and to the west alternately with each exposure. The temperature of the photographic house—in which there was no fire—was frequently read from a standard thermometer, the range being from $65^\circ\!\cdot\!7$ at $19^h\ 51^m$, to $75^\circ\!\cdot\!4$ at $23^h\ 38^m$. This latter was the time of the last exposure preceding interior contact at egress. After I had observed this contact optically, the exposures were resumed, and ten additional photographs were made. The total number of plates exposed was 147. Subtracting from this number all those exposed at the beginning of the day, the ten made between the two contacts at egress, a few worthless ones, and all others of doubtful value, the total number of plates available for micrometric measurement cannot fall far short of 125, and may somewhat exceed that number.

Before the plates were finally packed in boxes I made a comparative estimate, based on a somewhat rapid examination, of the value of these photographs of the Transit. Each plate was taken up in order and a mark assigned to it on the scale *A*, *A*—, *B*+, *B*, *B*—. The mark *A* means that the plate was judged to be of the very first quality, and capable of the most accurate measurement. Those marked *A*— are a shade inferior. Second-grade plates are designated by *B*; those a shade better, but not so good as *A*—, being marked *B*+; while those not up to the grade *B* are marked *B*—. A few were judged to be worth only a still lower mark, *C*. The result was as follows:—

A	71
A−	23
B+	13
B	9
B−	3
C	4
Total	123

After I had satisfied myself that no better place than the Observatory vault could be found for the temporary storage of these plates, they were, in great part, deposited there, together with such portions of the Photoheliograph as have yet to be investigated before the reductions of the photographic measurements can be completed. A few of the plates were brought to San Francisco, and placed in the vaults of the Safe Deposit Company of that city. The original record of the photographs was left in the Observatory vault on the mountain, duplicate and triplicate copies of it having been carefully prepared and brought down for preservation elsewhere.

Lawrence Observatory, Amherst, Mass.:
1883, *Jan.* 24.

Observations of the Transit of Venus, 1882, *Dec.* 6, *made at Mells, Ten Miles South of Bath.* By Maures Horner.

Instruments used:

A five-inch Equatorial Refractor, by Cooke, 1864, with position circle and clockwork.

A spectroscope of two prisms, dispersion about 15°, by Hilger; iridium slit shutting without spring, with milled head graduated to 1-900th of an inch. Prisms set to between C and D.

Sidereal time obtained from *α Cygni* by Troughton and Simms' portable transit instrument in conjunction with a Cooke pendulum-clock shortly after sunset.

The morning of the 6th was not quite without hope, for although the clouds appeared heavy, yet the wind kept nearly due north and the temperature low. At noon signs of a breaking in the sky became visible. All preparations were made, and some glimpses of the Sun obtained. The spectroscope was fixed, and the slit, 1-100th of an inch open, adjusted by means of the position circle tangentially as near to 145° as possible. At 1·30 G.M.T. the chromosphere was fairly well observed. Two small protuberances marked out the field of view; the larger one seemed to have rather a filamentary structure, and the space between appeared uneven, but not very active. At the place

where contact was expected it was difficult to keep the image of the chromosphere steady, nevertheless good views were secured. Clouds again came over a few seconds after two o'clock. Suddenly the sky cleared, and at $18^h\ 53^m\ 19^s{\cdot}5$ M S.T., at about 144°, between the two protuberances an appearance was observed of two dusky streaks like two faint Sun-spot lines. These were so marked, that after two or three seconds the observer called to his time watcher and took his eye off to look towards the clock, then looking again through the spectroscope he saw the single dark thick band stretching down the spectrum.

When the planet had made some progress on the Sun's limb the spectroscope was removed, and a transit eyepiece, power about 85, on the first surface-reflecting prism was applied.

The boiling of the limb became very violent, and sometimes the dark glass was unnecessary.

The first appearance that attracted notice was a distinct prismatic fringe round the edge of the planet, then projected on the Sun to the extent of about three quarters of its disk. This was seen through clouds without dark glass, time $19^h\ 9^m\ 7^s$ M.S.T. About a minute later, still without a shade, a faint hazy light was seen, which rapidly got more distinct, and appeared to encircle the part of the planet outside the Sun. Almost immediately the Sun shone out very clearly, making a neutral tint necessary, and at that moment the limbs of *Venus* could mentally be completed, and thus completed would appear to touch: time $19^h\ 11^m\ 36^s$ M.S.T. In half a minute more the light outside became exceedingly beautiful, but unfortunately a cloud floated by and contact was *estimated* at $19^h\ 12^m\ 41^s$ M.S.T. When the sky cleared at $19^h\ 13^m\ 19^s$ the observer was much surprised to see the planet not completely clear, and therefore this last time was imagined to be very near the moment of contact, as given on page 4 of the Instructions—viz. "when light is about to glimmer," &c. The times given are local sidereal time.

		m s
Longitude of Observatory from Ordnance Map	...	9 33·6
		° ′
Latitude " "	...	51 14

The beautiful hazy light outside the Sun's limb, immediately in the rear of the planet, was of considerable breadth; no bright line ring was noticed, nor was any regular black drop perceived, though any amount of such phenomena might have been manufactured out of the undulating limbs of the Sun and planet, especially if the focus had not been fixed before hand. The planet was carefully examined with all kinds of coloured glass and apertures, but nothing remarkable appeared except a distinct and persistent softening of the darkness towards the centre. One very beautiful display was made by a purple glass, which caused all the edges to glow with pink whilst the disks were blue. The most interesting effect was produced by a power of

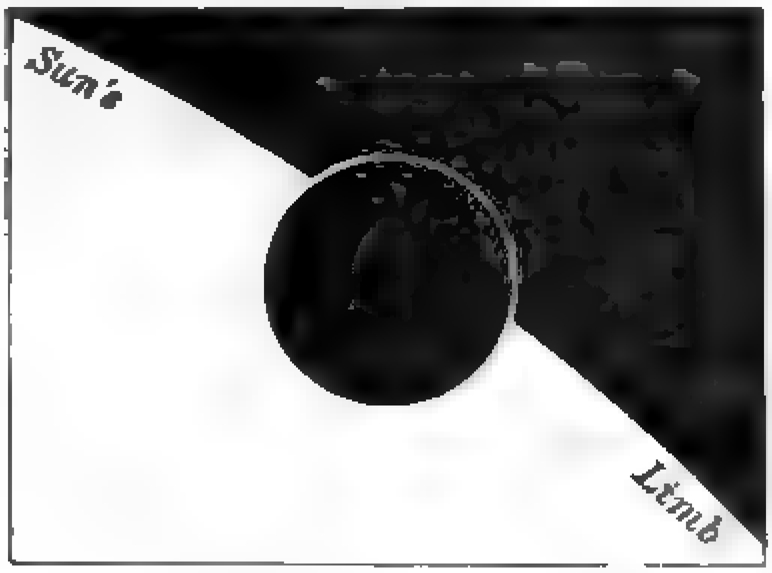
about 30, which gave more perfect idea of the planet's comparative nearness and of its suspension in space than did the higher powers.

The planet's disk was easily seen by the unassisted eye, and indeed without any protection by some young retinas when the Sun was near setting.

The spectroscope observations were made by the Rev. George Horner, and the remainder by the writer of these notes.

Note on the Transit of Venus, 1882, *Dec.* 6. By Charles Leeson Prince.

Since my communication to the Society of Dec. 7, respecting the Transit of *Venus*, I have had the following engraving made of the appearance of the planet's atmosphere shortly before internal contact, which, I trust, will be interesting to those who were not fortunate enough to witness the phenomenon.



The Observatory, Crowborough
1883, *Feb.* 5.

Notes on the Transit of Venus, 1882, *December* 6. By the Rev. Fred. Howlett.

The drawing of the late Transit—of which I obtained a few brief glimpses between the clouds—as seen projected on a screen in a darkened chamber, is of no really scientific value, but is interesting as showing how very conspicuous the phenomenon appears when observed by the method just mentioned.

Aperture used was 3 inches; focal length 45 inches; power 80. I first caught a view of the planet at about $2^h\ 5^m$, when it had advanced some $12''$ of arc over the Sun's limb. At the moment of first internal contact the Sun was completely clouded, but I obtained a good view of the planet when its following limb at $2^h\ 25^m$ was about $10''$ from that of the Sun. At this time *Venus* appeared slightly elliptical in a polar direction, and the "ligament" manifested itself at the time as a dusky, ill-defined, tremulous band intervening between the planet and the Sun's limb. The disk of *Venus* appeared of a very dark Indian-ink brown, and measured upwards of one inch in diameter on the screen. I did not observe any indications of an atmosphere, nor anything of the nature of a central spot of light.

From $2^h\ 26^m$ the Sun was overclouded for the rest of the afternoon.

1882, *Dec.* 8.

Note on Professor Newcomb's Remarks on the Windsor Observations of the Transit of Venus in 1874. By John Tebbutt.

Professor Newcomb, in his remarks (*R. A. S. Notices* for April 1882) on the Instructions of the Paris International Conference for observing the Transit of *Venus* in 1882 states, "that I failed to observe either contact in 1874 through waiting at ingress until almost every vestige of the ligament had disappeared, and at egress by endeavouring to catch its first formation." It is quite possible that Professor Newcomb's statements may to a certain extent be correct, but it is at all events certain that the errors of observation were not great, as the phenomena of the shadowy ligament extended over a very small interval of time. That the errors could not be so great as Professor Newcomb's remarks seem to suggest is conclusively shown by the general result arrived at by Lieut.-Colonel Tupman, in his paper on the Solar Parallax, in the *R. A. S. Notices* for June 1878. The residuals for the Windsor observations of internal contact at ingress and egress, after the rejection of certain observations from other stations, are $12^s{\cdot}1$ and $0^s{\cdot}7$ too late respectively. I do not think, however, that a perfectly satisfactory determination of the value of the Windsor observations can be arrived at till more accurate values are adopted for the longitudes of some of the stations. In the case of Sydney and Windsor I think there can be no doubt that the longitude requires a correction of about four and five seconds of time respectively. The value adopted for Windsor is that contained in the *Nautical Almanac*, which depends on the old and, I believe, erroneous longitude of the Sydney Observatory, combined with the telegraphic difference between the two stations. From a casual consideration of the question it seems probable that had the more correct longitude of Windsor (see *R. A. S.*

Notices, vol. xl. p. 440) been employed, the residuals of that place would have been small and numerically about equal, but affected with different signs, showing that the thread of light was very fine and of nearly the same breadth at both observed internal contacts. In conclusion I may remark that the definition was good at both contacts, and that the contacts themselves were observed under the same conditions as regard aperture and magnifying power.

Windsor, N. S. Wales:
1883, *Jan.* 23.

Observations of the Partial Solar Eclipse, 1882, *November* 10.
By John Tebbutt.

The weather was all that could be desired for the observation of this phenomenon, and the contacts were pretty well observed as follows:—

		d h m s	
First contact	...	Nov. 10, 19 16 21·2	Local mean time.
Last contact	...	10, 21 47 57·2	

The instrument employed was the 4½-inch Equatorial with the full aperture and a negative eyepiece magnifying 120 diameters, in combination with a diagonal prism and the necessary coloured shade. The instrumental conditions were precisely those under which the last Transit of *Mercury* was observed here. The definition was very fair, and the solar cusps were sharp throughout. The irregularities of the Moon's limb were also well seen, but I could not detect any portion of the limb off the Sun's disk. At $20^h\ 12^m\ 57^s\cdot5$ the Moon's limb made first contact with a roundish-black spot, and the last contact at total emersion was observed at $21^h\ 7^m\ 24^s\cdot8$. In addition to this isolated spot there was a large group of spots on the Sun's disk, and so conspicuous, indeed, was this group that it could be readily seen with a coloured glass without a telescope. One of the most interesting phenomena in connection with the eclipse was the behaviour of two black-bulb thermometers suspended vertically in free sunshine, and read off as far as practicable at intervals of five minutes. One of the instruments was *in vacuo* and the other in a glass globe containing air. The following table exhibits the variations of the readings:—

Mean Time. h m	Thermometer in Vacuo. °	Thermometer in Air. °	Mean Time. h m	Thermometer in Vacuo. °	Thermometer in Air. °
18 35	91·7	78·8	20 20	99·5	89·0
18 40	98·0	82·6	20 25	98·8	88·7
18 45	101·8	85·2	20 30	98·5	88·5
18 50	104·2	87·2	20 35	98·5	88·5
18 55	106·4	89·0	20 40	98·8	88·7
19 0	107·8	90·0	20 45	99·6	89·3
19 5	109·5	91·9	20 50	101·3	90·6
19 20	112·2	95·0	20 55	102·5	91·7
19 25	112·8	95·5	21 0	104·5	93·3
19 30	112·5	95·2	21 5	106·0	94·3
19 35	111·8	95·2	21 10	108·3	95·8
19 40	111·3	95·2	21 16	110·5	97·5
19 45	109·8	94·4	21 20	112·0	98·5
19 50	108·5	94·0	21 25	113·8	99·7
19 55	106·5	92·8	21 30	115·7	101·2
20 0	104·5	91·7	21 35	117·2	101·8
20 5	103·3	91·0	21 40	118·4	102·7
20 10	101·8	90·5	21 50	120·7	104·2
20 15	100·5	89·7	21 56	121·4	105·0

As the atmosphere was calm and the Sun unclouded during the forenoon, these readings afford a good representation of the heating effect of the Sun's rays. It will be seen that the minimum readings occurred nearly simultaneously with the greatest phase of the eclipse.

Windsor, N. S. Wales:
1882, *Nov.* 20.

Occultations of Stars by the Moon observed at Stonyhurst in 1882. By the Rev. S. J. Perry, F.R.S.

1882.		Phenomena.	Limb.	G.M.T. h m s	Remarks.
Sept.	5	Disapp. of 68 Orionis	Bright	12 5 46·5	Sky perfectly clear.
		Reapp. „	Dark	12 47 43·8	„
	21	Disapp. of B.A.C. 6536	Dark	7 46 45·0	Definition very good.
		Reapp. „	Bright	9 1 41·0	„
Nov.	26	Disapp. of χ^2 Orionis	Bright	10 32 30·8	Excellent observation.
		Reapp. „	Dark	11 37 10·3	

The observer throughout was Mr. J. Rooney.

Phenomena of Jupiter's Satellites observed at Stonyhurst in 1882. By the Rev. S. J. Perry, F.R.S.

	Satellite.	Phenomena.	G.M.T.	Corr. of N.A.	Observer.	Remarks.
1882, Jan. 18	3	Ec. D. Fading	5 10 50·9		W.C.	Definition excellent.
		Half light	5 17 22·4			
		Last seen	5 22 1·9	+4 0·9		
18	3	Ec. R. First seen	6 47 36·4	−7 29·6	W.C.	Observation very good. Thin clouds.
24	1	Ec. R. First seen	7 23 32·1	−0 0·9	J.R.	Definition very good.
		Half light	7 24 45·8			
		Full light	7 25 33·7			
Feb. 1	3	Oc. D. External contact	7 36 28·2		W.C.	Definition poor.
		Bisection	7 39 32·7			
		Last seen	7 43 27·5			
15	1	Tr. I. External contact	6 50 8·6		J.R.	Thin clouds passing.
		Bisection	6 52 36·9			
		Internal contact	6 55 46·7			
15	2	Oc. D. External contact	9 24 58·6		J.R.	Definition very good.
		Bisection	9 26 45·1			
		Last seen	9 28 37·5			
Mar. 11	1	Ec. R. First seen	7 57 4·2	+0 18·2	J.R.	Definition good. Haze; passing clouds.
		Half light	7 59 35·0			
		Full light	8 3 21·5			
12	2	Oc. D. External contact	6 53 29·7			
		Bisection	6 56 21·2			

	Satellite.	Phenomena.	G.M.T.	Corr. of N.A.	Observer.	Remarks.
		Last seen	6 58 28·7			
1882, Mar. 17	1	Tr. I. External contact	9 12 44·8		J.R.	Definition very poor.
		Bisection	9 16 24·3			
		Internal contact	9 18 1·6			
26	1	Tr. E. Internal contact	7 56 39·0		J.R.	Definition poor. Image very steady.
		Bisection	7 59 20·0			
		External contact	8 2 10·0			
28	3	Tr. I. External contact	11 39 35·8		J.R.	Definition very good.
		Bisection	11 46 32·0			
		Internal contact	11 51 46·2			
28	3	Tr. E. Internal contact	14 4 2·9		J.R.	Definition very good.
		Bisection	14 10 2·5			
		External contact	14 17 58·8			
Nov. 11	1	Tr. I. External contact	9 34 18·8		A.C.	
		Bisection	9 36 34·8			
12	2	Oc. R. First seen	8 58 27·8		W.McK.	Definition good.
		Bisection	9 0 57·3			
		External contact	9 3 59·3			
17	1	Ec. D. Half light	13 19 40·6		J.R.	Definition fair.
		Last seen	13 21 11·6	+0 38·6		
17	1	Oc. R. First seen	16 19 47·0		J.R.	Haze.
		External contact	16 22 45·1			

	Satellite.	Phenomena.	G.M.T.	Corr. of N.A.	Observer.	Remarks.
1882, Nov. 26	1	Ec. D. Last seen	9 43 35·1	+0 25·1	J.R.	Observation very good.
26	1	Oc. R. First seen	12 30 8·0		J.R.	Definition poor.
		Bisection	12 33 12·8			
		External contact	12 35 43·3			
27	1	Tr. I. External contact	7 25 25·4		J.R.	Definition poor.
		Internal contact	7 30 37·4			
Dec. 5	1	Ec. D. Fading	6 3 24·3		J.R.	Definition good.
		Half light	6 4 36·4			
		Last seen	6 5 45·6	−0 9·4		
5	1	Oc. R. First seen	8 36 55·6		J.R.	Definition good.
		Bisection	8 37 45·1			
		External contact	8 38 52·3			
10	3	Tr. E. Bisection	10 37 22·5		J.R.	Observation good.
		External contact	10 43 53·7			
10	1	Ec. D. Fading	13 29 42·0		J.R.	Definition very good.
		Half light	13 30 36·5			
		Last seen	13 31 51·1			
10	1	Oc. R. First seen	15 53 14·0		J.R.	
		Bisection	15 55 5·5			
		External contact	15 57 8·8			

The observations were all made with the 8-in. Equatorial, the observers being the Rev. A. Cortie, and Messrs. J. Rooney, W. Carlisle, and W. McKeon.

Observations of Occultations of Stars by the Moon, of Phenomena of Jupiter's Satellites, and of the Eclipse of the Sun, 1882, May 16, made at the Royal Observatory, Greenwich, in the year 1882.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day of Obs.	Phenomenon.	Telesc.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Obs.
1882.					h m s	
Feb. 24 (*a*)	Disapp. 53 Tauri	Altaz.	100	Dark	7 45 17·65	T.
Apr. 1	Disapp. *e* Leonis	E. Eq.	70	„	11 30 52·12	L.
May 27 (*b*)	Disapp. W.B. xii., 334	„	140	„	9 43 4·30	A. D.
	Disapp. W.B. xii., 334	Altaz.	100	„	9 43 4·90	H.
Aug. 2	Reapp. 22 Piscium	„	„	„	10 50 14·80	T.
Sept. 20	Disapp. μ Sagittarii	„	„	„	9 19 21·52	L.
	Disapp. μ Sagittarii	E. Eq.	70	„	9 19 21·82	A. P.
Oct. 1	Reapp. *l* Tauri	Altaz.	100	„	17 35 59·87	T.
2	Reapp. χ^2 Orionis	„	„	„	12 21 23·64	H.
22	Disapp. κ Aquarii	E. Eq.	70	„	10 25 13·27	T.
24	Reapp. 51 Piscium	Altaz.	100	„	11 49 32·39	H.
Nov. 26	Reapp. χ^2 Orionis	E. Eq.	70	„	11 38 1·94	L.

Notes.

(*a*) Star faint; cloudy.

(*b*) Instantaneous.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1882, Jan. 7	III.	Tr. Ingr. First contact	E. Eq.	140	6 29 57		
		Bisection	,,	,,	6 35 6	6 32 0	L.
		Last contact	,,	,,	6 39 56		
7	II.	Occ. D. First contact	,,	,,	7 29 38	7 32 0	,,
		Last contact	,,	,,	7 34 15		
7	III.	Tr. Egr. First contact	,,	,,	8 20 19	8 26 0	,,
		Last contact	,,	,,	8 30 6		
7	I.	Tr. Ingr. First contact	,,	,,	8 28 4	8 27 0	,,
		Last contact	,,	,,	8 33 9		
Feb. 15 (*a*)	II.	Occ. D. Last contact	,,	,,	9 28 6	9 29 0	,,
Mar. 3 (*b*)	II.	Tr. Ingr. First contact	,,	,,	9 47 11	9 54 0	A.D.
		Last contact	,,	,,	9 53 10		
17 (*c*)	I.	Tr. Ingr. First contact	,,	,,	9 14 35	9 15 0	H.P.
		Last contact	,,	,,	9 20 4		
Apr. 3	III.	Tr. Ingr. First contact	,,	,,	7 42 35	7 45 0	A.D.
6 (*d*)	II.	Ecl. R. First seen	,,	70	8 58 32	8 57 40	T.
Oct. 3	III.	Occ. R. Last contact	Altaz.	100	13 12 24	13 7 0	H.C.

Day of Observation.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1882, Oct. 4 (*e*)	I.	Occ. R. First seen	E. Eq.	140	11 0 40	11 2 0	H.P.
		Last contact	"	"	11 6 9		
25 (*f*)	I.	Occ. D. Last contact	"	"	13 11 39	13 10 51	L.
Nov. 17	I.	Ecl. D. Last seen	"	60	13 20 49	13 20 33	H.P.
25	I.	Tr. Ingr. Last contact	"	70	13 8 21	13 7 0	T.
27	I.	Tr. Egr. Bisection	"	"	9 48 10	9 48 0	H.
		Last contact	"	"	9 50 27		
Dec. 18	I.	Tr. Ingr. Last contact	"	"	12 49 54	12 44 0	T.
19	I.	Occ. D. First contact	"	310	9 47 28	9 50 0	A.D.
		Last contact	"	"	9 52 12		
19	I.	Occ. R. First seen	"	"	12 3 46	12 6 0	"
		Last contact	"	"	12 8 20		
21	I.	Ecl. R. First seen	S. E. Eq.	285	6 34 51	6 34 51	"
		Full brightness	"	"	6 38 10		
21 (*g*)	I.	Ecl. R. First seen	E. Eq.	310	6 34 41	6 34 51	L.

Notes.

(*a*) *Jupiter's* limb diffused. (*b*) *Jupiter's* limbs boiling: observation considered very rough. (*c*) Planet steady.
(*d*) " " (*e*) *Jupiter's* limb diffused. (*f*) *Jupiter* extremely tremulous: observation not considered good.
(*g*) *Jupiter's* limb very ill-defined.

Eclipse of the Sun, 1882, May 16.

Beginning and Ending of the Eclipse.

		Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Obs.
1882.					h m s	
May 16		First contact	S.E. Eq.	500	18 11 15·24	W.C.
	(*a*)	„	Altaz.	120	18 11 27·11	A.D.
		Last contact	S.E. Eq.	500	19 23 13·43	W.C.
	(*b*)	„	Altaz.	120	19 23 8·55	A.D.
		„	E. Eq.	70	19 23 9·25	M.
		,	N. Eq.	220	19 23 1·42	L.

Notes.

(*a*) Observation satisfactory. (*b*) Observation pretty accurate.

During the eclipse the following observations were made with the S.E. Equatorial:—

From 18h 13m to 18h 31m G.M.T.	10	differences of	R.A. of *p* and *f* cusps.
18 31 to 18 48	10	„	N.P.D. of limbs of Sun and Moon.
18 48 to 19 8	8	„	R.A. of *p* and *f* cusps.
19 8 to 19 22	9	„	N.P.D. of *p* and *f* cusps.

The clear aperture of the object-glass of the S.E. Equatorial is 12¾ inches, of the E. Equatorial 6¾ inches, of the Altazimuth 4 inches, and of the N. Equatorial 4·1 inches.

The initials W.C., A.D., M., T., L., H., H.P., H.C., are those of Mr. Christie, Mr. Downing, Mr. Maunder, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. H. Pead, and Mr. Cox.

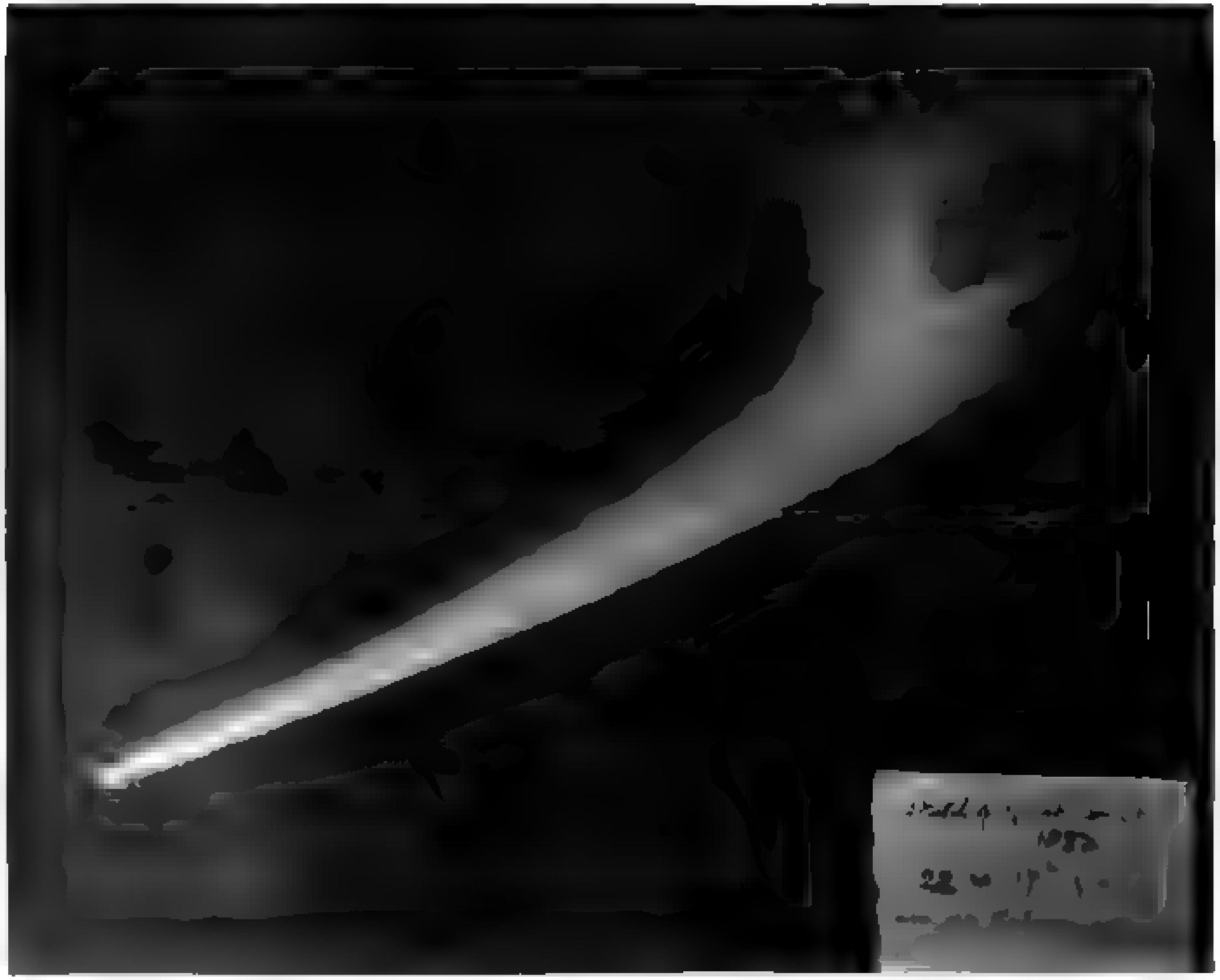
Royal Observatory, Greenwich:
1883, *January* 20.

Observation of Comet a, 1883, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observation was made with the East or Sheepshanks Equatorial, by taking transits over two cross wires at right angles to each other, and inclined 45° to the parallel of Declination.

Green. Mean Solar Time.	Obs.	☌—✱ R.A.	☌—✱ N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Star.
d h m		m s	′ ″		h m s	° ′ ″	
Mar. 8 9 0	H.	+0 11·0	−2 58·96	1	0 59 56·62	58 23 36·81	*a*



SKETCH OF THE GREAT COMET (*b*), 1882.

Mean Place of Comparison Star.

Star.	Star's Name.	R.A. 1883·0.	N.P.D. 1883·0.	Authority.
		h m s	° ′ ″	
a	σ^2 Piscium	0 59 45·24	58 26 40·50	Green. Cat. 1872.

Note.—The sky clouded immediately after the comet was found; only one comparison could be obtained.

The observation is not corrected for refraction or parallax.

Royal Observatory, Greenwich:
1883, March 9.

Observations of the Great Comet (b) 1882, *made at Grahamstown, Cape of Good Hope.* By L. A. Eddie.

The comet was first observed on September 13 at 4.50 A.M. It had then just risen above the horizon, and appeared in the strong twilight as a brilliant but narrow band of ruddy light, terminating in a very bright nucleus, equalling *Jupiter* in brilliancy and apparent size. The tail was slightly inclined to the north, but seemed to have no curvature. It could be traced to about 12° from the nucleus. When viewed through my 9½-inch Calver, it appeared as an extremely bright and well-defined nucleus of a solid appearance, and shining with a light quite equal to that of *Venus*, but of a light golden hue; it was surrounded by a dense coma of a ruddy-brown tinge; there was no appearance of envelopes, and its periphery was very sharply defined. The nucleus seemed to contract as the daylight increased until it reached a limit where the still increasing light had no further diminishing effects on its size. This would seem to indicate a very dense centre to the nucleus.

September 15.—Morning clear. Head of comet rose at 5.3. The nucleus shone as bright as *Jupiter*, but no important details of physical structure were observed. The nucleus could be seen with the naked eye up to 5.40.

September 16.—The comet rose at 5.15. In the telescope the nucleus appeared less sharply defined on its preceding boundary, and the breadth of the coma was greater on the northern side than on the southern. The tail seemed to spread out for a short distance behind the comet, and it was darker in the centre, as if split open.

September 17.—The comet rose at 5.44, about 14 minutes before the Sun. It had increased still more in size and brilliancy. The head and tail, about 8′ in length, shone with intrinsic lustre. It was not to be eclipsed by the sunlight to-day at all, but continued to shine during the whole day as a bright attendant to the Sun, of 1° in length, and in which the cometary form was plainly discernible. So apparent was it to the naked eye, that one had but to look in the direction of the Sun when it could immediately be seen without any searching. However, as the day advanced it approached the Sun so very rapidly that at

2 o'clock there was some little difficulty in screening the Sun from the view when looking at his attendant; and at 4.30 P.M. —which was the latest I was able to observe it, owing to its becoming obscured by clouds—it was so very close to the Sun as to be visible in the same field with this orb when observed through my 3-inch Refractor with a power of 50, being then about 14′ only from the Sun's western limb. In the 9-inch Calver this splendid object certainly presented a beautiful and imposing sight when it had risen sufficiently high to be free from the effects of the unsteadiness of the atmosphere in the vicinity of the horizon. The nucleus appeared as a solid globe glowing with a white light surpassing that of *Venus* when viewed in the daytime. The coma and tail for a short distance behind the head were also very brilliant. There was but little coma preceding the nucleus, so that the latter appeared as situated at almost the extremity of the tail. The coma was bounded on the margins by a denser stream of light than that composing its interior portion, and the northern side was narrower and brighter than the southern, but the southern extended further behind the nucleus than the northern. For this comet to have been not only visible during the whole day, but to have formed a conspicuous object in the heavens while in such close companionship with its brilliant ruler proves it to be the most brilliant comet of the present century, not excepting the great comet of 1843, which was also visible in full daylight, but not described as being visible during the whole day. To prove that it was not only visible in full daylight to one experienced in searching for heavenly bodies, I may here mention that my little girl, of only four years, was able to see it without difficulty up to about 1 o'clock, after her attention had been once directed to it. What is remarkable in this comet is that no great indications of perturbations taking place in its physical structure were observed while it approached the Sun, as is generally the case with these wonderful bodies, and especially with that of Comet *b* of 1881, as observed by myself.

September 19.—Comet observed at 8 A.M. about 4° N.W. of the Sun. It is now moving off in almost the same direction as it approached the Sun, so that it is apparently describing a very closed orbit of an elongated elliptical form.

September 20.—The comet rose at about 5.15 A.M. Though the head is decreasing in brightness, the tail has certainly greatly increased both in breadth and length. The tail appeared 5° in length and about 1½° in width. It spread out suddenly to a breadth of nearly 1° at about 2° behind the nucleus, and then continued to open out at a less angle.

September 24.—On observing the comet at 4.30 A.M. a most glorious sight presented itself. The head of the comet had not yet risen, but a broad brilliant belt of rich golden light, about 2° in breadth, streamed upwards from the horizon for about 10°; and from the northern margin of this, again, a thin streak of less brilliant light extended upwards for about another 12°, and when

the head had fully risen above the horizon at 4.43 A.M., there were about 25° in length of intensely luminous matter stretching upwards from a still more brilliant head, and inclined to the horizon at an angle of 70°. This glowing glory of light was more intensely brilliant on its margins, which represented two streams of incandescent gas flowing out from the preceding portion of the nucleus for a short distance, and then bent backwards so as to form the boundaries of its luminous appendage. The northern streamer was rather more brilliant than the southern, and possessed a slight bowing or outward curvature near the head of the comet, and further it was bounded on its interior edge by a dark rift or interval, which extended from the nucleus to nearly the termination of the broad part of the tail, and though it appeared very dark indeed when viewed with the luminous portion in close juxtaposition with it, it was nevertheless detected to possess a small degree of luminosity when viewed alone. The head appeared as before to consist of an apparently very solid though not very large nucleus, surrounded by a dense coma of no great extent, especially preceding the nucleus, and possessing no dark intervals, envelopes, or indeed any remarkable details as were so very conspicuous in Coggia's Comet of 1874, and in Comet *b* of 1881. As daylight advanced it soon became apparent that the comet, though not before seen to so great advantage, owing to its rising earlier, and consequently projected on a darker background, had greatly decreased in brilliancy and apparent size, for it was eclipsed by the increasing daylight, about 12 minutes before sunrise, when *Jupiter* was yet plainly visible. The Sun rose about 4.49.

October 3.—The comet rose at 3·35, and could be then seen, through the dense fog that prevailed, like a great flame proceeding from a bonfire on the hills. At 4 A.M. when the fog had cleared away, it was at once perceptible that a great change in the structure of the comet had taken place. The tail was about 15° in length, and 3° in breadth at its extremity. The light was much more diffused throughout the whole length and breadth than before. The bright streams of light on the margins had disappeared; but the southern side was brighter, more sharply defined, and seemed to consist of denser matter than the northern, which was ragged in some parts, and shaded gradually in others. The dark rift which formed so conspicuous an object on September 24 was still present, but appeared to be closing up. There was a less sharply defined dark rift proceeding from the centre of the extremity of the tail to about $\frac{1}{4}$ its length towards the head, not parallel with the tail, but, following it with the eye from west to east, it appeared to incline more to the northern margin. The long, but faint, extension of the tail on the southern side was not visible; but this was probably owing to the strong moonlight, for when the tail was viewed by a side glance, a slight extension of the southern margin beyond the northern could be traced. The intense brilliancy of the tail to about two degrees behind the nucleus,

which was plainly perceptible in this comet even when viewed in the daytime, has almost entirely left, and seems to be diffused throughout the whole tail, so that the extremity is now almost as brilliant as the portion immediately behind the nucleus. The head and one-fourth of the northern margin of the tail to about 3° behind the head were shrouded by a faintly luminous envelope of very rare matter one-fourth of a degree in width. The southern margin of the tail was, as I have already stated, very sharply defined, and possessed a slight though decided curvature.

On examining the nucleus with the 9½-inch Calver, to my astonishment I observed that it consisted of two distinct ellipsoidal nuclei in juxtaposition, each of them brighter on the interior edge and drawn out as it were towards the comet's ulterior boundary so that their conjugate axes were about double their transverse. They closely resembled, in the inverting telescope, the flames of two candles placed the one above the other, so that the uppermost part of the lower flame almost overlapped the lower portion of the other. There was a dark rift the breadth of the transverse axes of these nuclei extending from the hindermost one into the tail. These two nuclei were not parallel with the axis of the comet, but the foremost was drawn as it were, to the south or nearer to the direction in which the comet is moving. These two gaseous bodies appeared exactly as the double star *a Centauri* when viewed through a cloud with a low power. When the daylight had partly advanced they could be seen in the telescopic field perfectly free from the light of the surrounding matter forming the coma. This goes to prove what I have above stated, that the brilliancy of the matter immediately around and behind the nuclei has now greatly declined, for a considerable portion of the luminous matter forming the coma and tail was always visible on former occasions in the telescopic field when observing the nucleus, even at midday and when close to the Sun.

The comet became invisible this morning at 5.17, when the first-magnitude stars were yet shining brightly. The Sun rose at 5.35.

October 4.—Comet this morning very beautiful, owing to the sky being perfectly free from cloud or mist of any description. At 4 o'clock the prolongation of the southern margin of the tail could be traced for a short distance beyond the normal tail. The dark rift extending the whole length of the tail was still less distinct, and seems to be fast disappearing. The thin gauze envelope around the head and part of the tail is becoming more extensive, being in some parts nearly one degree in width, and it appears to melt into and form a continuation of the gradual shading off of the northern margin of the tail, which was this morning much less ragged. If it were not for the strong moonlight this thin veil would form a very beautiful and conspicious feature in this comet. When viewed through the finder it appeared sharp and well-defined, and extended for a considerable distance beyond the nuclei. The nuclei this morning were dis-

tinctly divisible viewed in the Reflector with powers of 60 and 100. They appeared if anything smaller than yesterday. The preceding nucleus was larger and brighter than the other, and they resembled in shape two grains of rice placed end to end.

October 8.—The dark rift that extended through the tail near its southern margin has entirely left, though the appearance of longitudinal streaks is still more apparent on this side. The abnormal tail could be traced for about 3° beyond the normal tail, making a sort of ogee-shaped figure on the extremity of the southern margin of the latter. In the finder, the thin gauze veil observed October 4, which envelops the head, as it were, with a hood, could be distinctly seen spreading out on either side of the head and extending to a considerable distance in front of the head in a cometary form, but lost to vision or fading away at the extreme limit of the cone. The nucleus, when viewed with the 9-inch Calver, powers 60 to 100, was very indistinct, owing partly no doubt to the unfavourable state of the atmosphere for observation; the preceding portion of the nucleus was shining brightly and did not seem to have altered since I last saw it, but the following portion was as if drawn out, and the light condensed at either end of the longer axis, so as to give the whole nucleus a triple appearance, but without any distinct separation between the two parts as before observed, or between the three apparent centres of condensation; it resembled a bar of dim light threaded with three beads of greater brilliancy, the foremost a long oval one, the others round, smaller and less brilliant. The light of the waning moon was unfavourable to observing details in the structure of the comet.

October 9.—Morning clear, but wind very strong and atmosphere unsteady. The light midway in the length of the tail is rather dimmer than at either of the extremities. Nucleus had much the same indistinct triple form as yesterday, and is now surrounded by very little coma. The hood surrounding the head, when viewed through the finder, has still the same beautiful appearance.

October 11.—Morning very fine, with clear sky and steady atmosphere. The thin gauze hood to the head of the comet was faintly discernible to the naked eye for about $1\frac{1}{2}°$ in front of the nucleus, and this feature is still very beautiful in the finder. I obtained this morning a much more satisfactory view of the nuclei than I did on October 8 and 9. They have greatly altered in shape since I first detected the division, and they have also somewhat considerably opened out. The preceding nucleus is now much smaller and condensed into a very bright starlike point, from which spiral streams seem to emanate. The hindmost nucleus has become greatly elongated, and now possesses as it were two centres of condensation, and appears to be fast approaching to a further division. This elongated nucleus resembles a dumb-bell with the sphere towards the tail more oval than the other. When the splitting up of the nucleus was first discovered by me, the two portions

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1882, Jan. 7	III.	Tr. Ingr. First contact	E. Eq.	140	6 29 57		
		Bisection	,,	,,	6 35 6	6 32 0	L.
		Last contact	,,	,,	6 39 56		
7	II.	Occ. D. First contact	,,	,,	7 29 38	7 32 0	,,
		Last contact	,,	,,	7 34 15		
7	III.	Tr. Egr. First contact	,,	,,	8 20 19	8 26 0	,,
		Last contact	,,	,,	8 30 6		
7	I.	Tr. Ingr. First contact	,,	,,	8 28 4	8 27 0	,,
		Last contact	,,	,,	8 33 9		
Feb. 15 (*a*)	II.	Occ. D. Last contact	,,	,,	9 28 6	9 29 0	,,
Mar. 3 (*b*)	II.	Tr. Ingr. First contact	,,	,,	9 47 11	9 54 0	A.D.
		Last contact	,,	,,	9 53 10		
17 (*c*)	I.	Tr. Ingr. First contact	,,	,,	9 14 35	9 15 0	H.P.
		Last contact	,,	,,	9 20 4		
Apr. 3	III.	Tr. Ingr. First contact	,,	,,	7 42 35	7 45 0	A.D.
6 (*d*)	II.	Ecl. R. First seen	,,	70	8 58 32	8 57 40	T.
Oct. 3	III.	Occ. R. Last contact	Altaz.	100	13 12 24	13 7 0	H.C.

Day of Observation.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1882, Oct. 4 (*e*)	I.	Occ. R.	First seen	E. Eq.	140	11 0 40	11 2 0	H.P.
			Last contact	„	„	11 6 9		
25 (*f*)	I.	Occ. D.	Last contact	„	„	13 11 39	13 10 51	L.
Nov. 17	I.	Ecl. D.	Last seen	„	60	13 20 49	13 20 33	H.P.
25	I.	Tr. Ingr.	Last contact	„	70	13 8 21	13 7 0	T.
27	I.	Tr. Egr.	Bisection	„	„	9 48 10	9 48 0	H.
			Last contact	„	„	9 50 27		
Dec. 18	I.	Tr. Ingr.	Last contact	„	„	12 49 54	12 44 0	T.
19	I.	Occ. D.	First contact	„	310	9 47 28	9 50 0	A.D.
			Last contact	„	„	9 52 12		
19	I.	Occ. R.	First seen	„	„	12 3 46	12 6 0	„
			Last contact	„	„	12 8 20		
21	I.	Ecl. R.	First seen	S. E. Eq.	285	6 34 51	6 34 51	„
			Full brightness	„	„	6 38 10		
21 (*g*)	I.	Ecl. R.	First seen	E. Eq.	310	6 34 41	6 34 51	L.

Notes.

(*a*) *Jupiter's* limb diffused. (*b*) *Jupiter's* limbs boiling: observation considered very rough. (*c*) Planet steady.
(*d*) „ „ (*e*) *Jupiter's* limb diffused. (*f*) *Jupiter* extremely tremulous: observation not considered good.
(*g*) *Jupiter's* limb very ill-defined.

could not be detected, and the division between the two portions was very much smaller and less distinct.

November 2.—Morning fine; atmosphere clear; moon nearly the same altitude as comet, but considerably to its north. Nucleus was resolved into the six points by the 9½-inch mirror; the fifth and sixth require now a very clear morning in order that they may be detected, but this morning they were clearly visible. The two principal points, Nos. 2 and 3, were very bright.

November 10.—Sky covered more or less with cirri. Observed comet from 3.30 A.M. till eclipsed by daylight. Nucleus appeared to unaided eye much brighter and more star-like. With the mirror I was able to see all the points except the sixth, also the division between Points Nos. 2 and 3. The last formed point (No 1) has dimmed less than the others, or is, in other words, comparatively brighter than formerly. It is also now situated at a further distance from its neighbour than any of the others are from each other. The nucleus was visible to the naked eye up to 4.20—that is, thirty-three minutes before sunrise, which was at 4.53. This fact shows that there is apparently no diminution in the light of the nucleus since October 23 last, when, according to my own observations of that date, the comet faded from sight at 4.35 A.M. (the Sun rising at 5.10) or thirty-five minutes before sunrise. Its apparent movement is at present very small.

Ncvember 17.—Comet visible for a short time from 2.30 A.M. to 3.15 A.M. I could still, when using the 9½-inch Calver, detect at intervals five of the bright points in the nucleus. I thought Point No. 5 twinkled into sight more often than it had for some time back, while Point No. 1 could, on this occasion, scarcely be detected. Point No. 6 has now quite disappeared. These extremely tiny points of light, situated as it were in a nebulous mist, and revealing themselves at intervals on very favourable nights only, by their twinkling do indeed present a wonderful phenomenon.

November 24.—Sky clear; moon nearly full and very bright. The nucleus of the comet when viewed in the telescope still presented the appearance of a bar of light, but I could distinguish only two of the points of light, which I could not identify.

November 27.—Nucleus in 9½-inch Calver appeared granulous.

November 31.—The tail of the comet is still about 12° in length, and rather wider than formerly. The extremity has greatly altered in form, being now very much curved downwards to the east, in the form of a shepherd's crook, and closely resembling an ostrich plume with a drooping tip. The extremity is fully 6° in width. On examining the nucleus in the telescope, Point No. 1 could be seen very far removed from Point No. 2, which latter, together with No. 3, could be discerned on close observation.

December 2.—Sky hazy. Comet bright. The hooked extremity of tail plainly discernible.

December 4.—Nucleus seen at intervals between the breaks in the clouds. Three of the points dimly visible: the streak of light, which now alone forms the centre of the nucleus, resembles a string of luminous beads almost hidden by a luminous gaseous veil stretched over them. A decided change is going on in the nucleus, which does not seem to be decreasing much in brilliancy at present. The tail was tolerably bright for about 8° from the nucleus, when it became very faint, and the "shepherd's crook" was scarcely visible. It was about 2° in width, at a distance of 4° from the head.

December 5.—Comet fainter. Nucleus oval and granulous.

December 9.—Comet resembles an elliptical nebula condensed along its conjugate axis. I can no longer detect the points.

The comet was observed on every day that it was visible from September 13 to December 14, the telescope employed being a 9½-inch silvered-glass Reflector by Calver.

Grahamstown, Cape of Good Hope.

On the Magnifying Power of a Telescope. By J. M. Schaeberle.

(*Communicated by W. H. M. Christie.*)

I have lately devised a very simple arrangement by means of which the magnifying power of a telescope can be determined with almost any desired degree of accuracy. The only apparatus required is a thin wooden arm about two feet in length, by three or four inches in width at one end, tapering to an inch or less at the other end, and pierced by two fine needles, one near each end of the arm. The needle near the wide end is driven into a table, or any horizontal surface, and serves as an axis about which the arm can be revolved. Directly over this axis the eyepiece is placed in such a position that a narrow slit not more than $\frac{1}{100}$ of an inch in width (formed by fastening two pieces of tin or paper over the opening in the cap which covers the eye-end of the ocular) shall be coincident with the prolongation of the axis of rotation. The optical axis of the eyepiece having been made horizontal, the observer, stationed behind a second but wider slit placed at a distance of several feet from the ocular, and on the same level with it, marks the two positions of the arm (by pricking holes into the table with the other needle) at which the diffused light, passing first through the eyepiece, then through the narrow slit towards the observer, is occulted by the diaphragm in the focus of the eyepiece. If r denotes the distance between the needles, and d the distance between the two prickings in the table, the angle A, subtended by a diameter of the diaphragm, as seen through the eye-end of the ocular, will be given by the equation

$$\sin \tfrac{1}{2} A = \frac{\tfrac{1}{2} d}{r}.$$

If t denotes the time required for a star, near the meridian

and having the small declination δ, to cross a diameter of the diaphragm, the eyepiece being now attached to the telescope, the expression for the magnifying power P will evidently be

$$P = \frac{\tan \frac{1}{2} A}{\tan \frac{1}{2} (15 . t \cos \delta)}$$

essentially the formula given by Rev. W. Dawes in vol. xxiii. of the *Monthly Notices* of the Royal Astronomical Society. This ardent astronomer there gives a way for finding this angle directly, but for several reasons the results obtained by the method can only be regarded as rude approximations, and he evidently so considered them at the time, for in the same paper he concludes that probably a more accurate way for finding this angle would be to deduce it from the known magnifying power determined by other methods. Now, a comparison of the results obtained by the different methods with which I am familiar leads me to affirm that the most accurate procedure by far, for determining the magnifying power, involves the *direct measurement* of the angles subtended by the diaphragm (or any other plane figure placed in the common focal plane of the objective and eyepiece) as seen from the object and eye ends of the telescope.

An example showing the superiority of this method over the one most commonly given will best illustrate what has been claimed above. Let the effective diameter of the object-glass be 9 inches, and the actual magnifying power 300. The theoretical diameter of the image of the object-glass as formed by the eyepiece when it is placed in the stellar focus will be 0·03 inch. Now, the mean of a most careful series of measurements of the diameter of this image, called the bright spot, may easily be in error several thousandths of an inch: an error of only one one-thousandth of an inch would cause an error of ten diameters in the resulting magnifying power. If we suppose that a diameter of the diaphragm in the eyepiece subtends an angle of 6′ at the objective, we have the following figures:—

Measured Diameter of Bright Spot.	Resulting Power.	Resulting Angle A.
in.		° ′
0·029	310	30 16·5
0·030	300	29 20·5
0·031	290	28 24·2

Now, granting that the mean of a series of *direct measures* of the angle A is in error one whole minute of arc, the resulting power will be in error only 0·18 of one diameter. In general, if n represents the number of minutes of arc subtended at the objective by a diameter of the diaphragm in the stellar focus, and x the number of minutes that the angle A is in error, the

number of diameters or parts of a diameter that the resulting power is in error will be

$$\frac{e}{a}.$$

The angle A will be slightly in error if, when measuring, the slit on the eyepiece is not directly over the axis of rotation; this parallactic error can be rendered insensible by removing the fixed slit, behind which the observer is stationed, to a greater distance, an assistant rotating the arm. If the observer possesses a spyglass (or temporarily constructs one made of two lenses) having a wire or straight-edge placed in the field of view, more accurate and convenient measurements can be made, as both slits can then be dispensed with, the spyglass being focused on the diaphragm as seen through the eye-lens in a negative ocular or a single-lens eyepiece, and both lenses in a positive one. Moreover, the parallactic displacement of the lens due to its eccentric position as it revolves about the axis of rotation now introduces no error in the measurements, so that the telescope can be placed close to the eyepiece.

If a theodolite, having a finely-graduated horizontal circle, is available, the eyepiece can be placed over the vertical axis and the angle, measured as above, deduced from the circle readings.

It is hardly necessary to state that the diaphragm, or wires, used in determining the magnifying power, should not be at too great an angular distance from the optical axis of the eyepiece, the fixed star, used in determining the time of transit, should still be in good focus when near the edge of the field of view, and instantly occulted as it apparently touches this edge.

To find the focal constant of the eyepiece with great accuracy the distance between the stellar focus of the objective and the optical centre of the object-glass must first be determined, and probably the simplest as well as the most reliable method for finding this constant is to rule three fine straight lines upon a piece of mica plate, one of the lines being drawn at right angles to the other two; the distance D between the parallel lines subtending, at the objective, an angle of from 25′ to 50′ when placed symmetrically with respect to the optical axis in the stellar focal plane. If τ denotes the time required for the image of a star near the meridian, and having the small declination δ (viewed with a positive movable eyepiece which can be held in the hand), to pass over the linear distance D on the plate, the focal constant F of the objective will be given by the equation

$$F = \tfrac{1}{2} D \,.\, \tan\left(90^\circ - \frac{15}{2} \tau \,.\, \cos \delta\right).$$

The expression for the focal constant f of the eyepiece is then :—

$$f = \frac{F}{P},$$

P being determined from the direct measurements of the angles

subtended by any plane figure placed in the common focus of the objective and eyepiece as seen from the two ends of the telescope.

Ann Arbor, Mich.. 1883, *Feb.* 5.

Physical Observations of Jupiter. By W. F. Denning.

Mr. Marth has discussed (*Monthly Notices*, vol. xlii. pp. 427–433) the observations of the white equatorial spot made between 1880, Aug. 27, and 1882, Aug. 7, and finds the rotation period $9^h\ 50^m\ 7^s{\cdot}42 = 878^\circ{\cdot}46$ daily rate. This is the same object as that observed by Prof. Hough (Annual Report of the Dearborn Observatory, 1882, pp. 50, 51) from 1880, Oct. 28, to 1882, March 31, and for which he has determined the period to be $9^h\ 50^m\ 9^s{\cdot}8$. The great red spot which has formed so conspicuous an object on the planet during the few preceding years has now become extremely faint, and it appears probable that it may shortly disappear. Its retarded motion continues. On 1883, Mar. 18, it crossed the planet's central meridian $1^h\ 29^m{\cdot}4$ after the assumed first meridian, as computed by Mr. Marth from the period $9^h\ 55^m\ 34^s{\cdot}47$ ($=870^\circ{\cdot}42$ daily rate). Relatively to this adopted time of rotation the spot has lost about 4^m per month, owing to its slackening velocity, since early in May 1881. The comparative motion of this red spot and of the white equatorial spot continue to afford some interesting results. From observations on 1883, March 15, the epoch of conjunction of the two markings was found to be, 1883, March 15, $13^h\ 38^m$. The figures show that since 1880, Nov. 19, $9^h\ 23^m$—a period of $846^d\ 4^h\ 15^m$—the white equatorial spot had completed 19 revolutions of *Jupiter* relatively to the red spot, the number of rotations performed by the latter being 2045 and by the former 2064. The white spot continues to be as brilliant and well-defined as when it first attracted notice, and gives promise to remain visible for a very lengthened period.

Bristol: 1883, *March.*

Note on Observations of Mercury. By W. F. Denning.

I obtained observations of this planet just before sunrise on the mornings of November 6, 7, 9, and 10, 1882, with my 10-inch Browning Reflector, power about 212. Some dark, irregular spots were distinctly seen upon the planet; also a small brilliant spot, and a large white area between the E.N.E. limb and terminator. The south horn was also much blunted, especially on the two first dates of observation. My results have led me to infer that the markings upon *Mercury* are far more decided and easily discernible than those on *Venus*; and that the aspect o the former planet presents a close analogy to the physical appearf ance of *Mars*. The rotation period of $24^h\ 5^m\ 30^s$ given b- Schröter seemed too short to conform with the relative plac y

of the markings as I delineated* them on the several dates referred to; and I wrote to Sig. Schiaparelli, of Milan, enclosing him the particulars of my results, as he has latterly been observing this planet with signal success. In discussing my notes he says:—"You were right in saying that this planet is much easier to observe than *Venus*, and that his aspect resembles *Mars* more than any other of the planets of the solar system. There are spots sometimes partially obscured and sometimes completely so; there are also brilliant white spots in a variable position. You are also right in suspecting that the rotation of Schröter was not exact." Sig. Schiaparelli mentions that his most successful results have been obtained with the planet near superior conjunction, when the defect of the diameter was compensated for by seeing nearly all the disk, which is then more strongly illuminated than near dichotomy.

I wish to call brief attention to these observations, in the hope that observers having equatorially-mounted instruments will examine the planet near superior conjunction. Sig. Schiaparelli has evidently utilised his favourable climate and instrumental means to obtain some important clue to physical phenomena of much interest on this systematically neglected member of our system.

Bristol: 1883, March 5.

On the Account of William Ball's Observation of Saturn in the Philosophical Transactions. By Henry T. Vivian.

I have read with great interest the paper by Professor Adams on this subject in the January number of the *Monthly Notices*; but notwithstanding the able manner in which he has dealt with it, it does not appear to me that the difficulties connected therewith, of which he speaks in the early part of his paper, have been altogether removed. There is an explanation, which perhaps has not occurred to Professor Adams, that, I think, may do something towards rendering the matter a little less obscure, and which will make the account in the *Philosophical Transactions* consistent with Ball's observation and his own account of it in his letter.

If we look at the request of the "Person to whom notice was sent" as an attempt to revive, in opposition to Huyghens, the opinion of Hevelius, that *Saturn* was elliptical and enclosed between two circular-shaped bodies, one on each side of him, we shall have this fully supported by the observation of October 13, as may easily be seen by supposing the outline of the planet in fig. 3 to be completed. The account of Ball's observation may then be considered accurate, and the figure correct. This view of the matter appears also to be supported by Ball's first letter of April 14. That letter alludes to observations made in three

* These drawings are on the eve of publication in the French serial *L'Astronomie*.

several years—viz. in 1664, the autumn of 1665, and in 1666. In 1664, he says, the figure of *Saturn* was the same as in 1666 —*i.e.* like the small fig. at the end of the postscript; and that in 1665 it was "what Sir R. Moray communicated," which is, no doubt, that alluded to in the account in the *Philosophical Transactions*, and represented in fig. 3.

One other point is perhaps worth inquiry. The Ball referred to by Huyghens is spoken of as D. Ball, whilst the Ball of the *Philosophical Transactions* is William Ball. May they not have been two different persons?

London: 1883, *March* 3.

[*Note on the above Paper, by Professor Adams.*—The explanation seems to be that the account of Ball's observation is accurate, and the figure given in the *Philosophical Transactions* correct. But this ignores the fact that all modern observations show that *Saturn's* ring has no such figure as that represented by the paper cutting, and it also supplies no reason for the suppression of the plate containing the extraordinary figure of the ring. The suggestion that the D. Ball spoken of by Huyghens is a different person from the William Ball who made the observations is quite untenable. Huyghens wrote in Latin, and D. Ball is merely an abbreviation for *Dominus* Ball. There were two Balls, William and his brother, but the former was the astronomical observer.]

Report of the Work of the Royal Observatory, Cape of Good Hope, during the year 1882. By David Gill.

During the past year the general programme of last Report has been systematically followed, and some additional researches have been undertaken.

1. The observations for the telegraphic connection of the longitudes of Aden and this Observatory, including the necessary personal-equation determinations, were completed on February 22, 1882, and the places of all the stars employed in the work have been re-observed with the Transit Circle.

The reductions of all these Transit Circle observations and of the personal-equation determinations are completed, as also are the determinations of clock error at all the stations except Aden. The latter were delayed in expectation of recent places of a few Northern circumpolar stars. The whole of the reductions of this work will now be completed within a few weeks.

2. The places of the Moon from Hansen's Tables, corresponding to the instants of occultations observed at the Cape previous to 1860, have been communicated by Professor Newcomb. The resulting equations have been computed, and the complete work only now requires the application of small corrections for error in the assumed longitude of the Cape.

3. The Cape Catalogue for 1850 has been delayed in comple-

tion by the severe pressure of current work, and this pressure has been increased by the illness of Mr. Freeman, Fourth Assistant. The reduction of corresponding stars in Mr. Stone's Catalogue to the Equinox of 1850 has, however, been made, and the whole only now requires final revision and comparison.

4. The meridian observations of 331 standard stars for the future zone observations of Professor Schönfeld's *Durchmusterung* from N.P.D. 90° to 120°, as also of the specially selected stars observed for refraction in conjunction with Leiden, have been proceeded with. The requisite number of observations have been obtained for all these stars except for some of those between 22^h to 5^h R.A. inclusive—where the observations of *Victoria* and *Sappho*, and the absence of observers in connection with the Transit of *Venus*, interfered to prevent their completion.

The meridian observations of the past year also include circumpolar stars, comet comparison stars, special observations of α and β *Centauri*, stars used in researches in stellar parallax, zones of stars observed in conjunction with the German Transit of *Venus* Heliometer expeditions, stars of which occultations by the Moon have been observed, and some comet observations.

In the year 1882 the number of observations with the Transit Circle has been as follows:—

In Right Ascension	... ...	4530 observations
Polar Distance	... ...	3844 „

248 determinations of level, 253 of azimuth, 161 of collimation.

The observations are all reduced to the end of 1882, but examination is in arrear for the greater part of that year.

5. Thirty-six occultations of stars by the Moon have been observed during the year 1882.

6. *Comets.*—Comet *Wells* was observed with the 8½-ft. Equatorial on thirty-nine days between June 14 and August 16 inclusive. The results are published in the *Monthly Notices* (vol. xliii. No. 1).

It was also observed on seven days between June 17 and 25 with the Heliometer.

The Great Comet of 1882 was observed by Mr. Finlay, Chief Assistant, at 17^h on September 7. His observations of that morning appear to be the first accurate determination of the place of this remarkable body.

The Great Comet has been observed here since that date on every day on which it has been visible, and the following observations have been secured (till 1883, February 4, inclusive):—

With the Heliometer	... ...	31 observations
Equatorials	... ...	65 „
Transit Circle	...	17 „
Altazimuth	... ...	3 „

The comparison stars are under observation with the Transit Circle.

The unprecedented observation of the disappearance of this comet at the Sun's limb was made by two observers on September 17 (*Monthly Notices*, vol. xliii. No. 1).

Successful photographs of the comet were secured on six days. The last three of these show some details that could not be so distinctly seen with any telescope or opera-glass, and all stars down to 8 or 8½ magnitude are shown. Paper copies have been forwarded to the Society.

A long series of drawings and measures of the nucleus have been secured.

Barnard's Comet has been observed with the Transit Circle S.P. on nine days.

7. The long series of Heliometer observations (referred to in last Report) undertaken for determining the annual parallax of the more remarkable Southern stars is nearly concluded, and the results will be ready for publication before the end of the current year.

8. The observations of *Victoria* and *Sappho*, for determining the solar parallax by Galle's method, were carried out in July, August, and September, according to the programme circulated by H.M. Astronomer at the Cape.

Victoria was observed on 54 nights.
Sappho „ „ 22 „

The following Reports have been received from Directors of Observatories who have kindly co-operated in the scheme :—

	Victoria.	Sappho.
Dr. Ball, Dunsink ...	12 nights	10 nights
Dr. Engelmann, Leipzig...	21 „	11 „
Prof. Bredichin, Moscow .	36 „	4 „
„ Krueger, Kiel ...	14 „	7 „
„ Schultz, Upsala ...	19 „	9 „
Dr. de Ball, Bothkamp ...	9*	

* This Report only extends to Sept. 3; the observations were being continued.

No Reports have yet been received from Paris, Strassburg, Potsdam, Clinton (U.S.), or Rio di Janeiro. A comparison between the observations of Gill and Elkin at the Cape with different telescopes, shows (if the observations of both observers are assumed equally good) that the probable error of one measure (eight bisections) is $\pm$ 0″·16.

Details of observations have as yet only been received from Dunsink, Leipzig, and Moscow. From these three Observatories, and for *Victoria* alone, there are sixty-four comparisons of $\Delta\,\delta$ in the Northern hemisphere, which correspond with a like number of separate comparisons at the Cape; or, if corresponding comparisons are not restricted to the same night, there are seventy-eight of such corresponding comparisons.

There is, therefore, reasonable ground to conclude that the

resulting value of the solar parallax from the whole of these observations will probably be at least as valuable as that derived from the Transit of *Venus* expeditions.

Victoria and *Sappho* have also been observed on the meridian—

Victoria on 37 nights.
Sappho on 18 „

The whole of the comparison stars (seventy-two for *Victoria* and sixty-six for *Sappho*) have also been observed on the meridian at least three times each; the more important stars much oftener.

The Heliometer observations of the "Scale-Value" and "Distortion-Stars" are not yet completed, but will be so in June and July of the current year.

9. The Observatory has co-operated to its utmost extent in the observations of the Transit of *Venus*. Mr. Finlay, Chief Assistant, and Mr. Pitt, Third Assistant, occupied a station at Aberdeen Road. Both contacts at ingress were observed by both these observers. The observations for time, latitude, and longitude at Aberdeen Road are reduced, and the results have been communicated to the British Transit of *Venus* Committee.

At this Observatory the internal contact at ingress was observed by six observers, and a number of Heliometer observations of the least and greatest distance of the centre of *Venus* and the Sun and of the diameter of *Venus* were obtained.

Programmes for longitude operations, and lists of time and azimuth stars were prepared for the Transit of *Venus* stations at Montague Road (British) and Wellington (American), and the necessary time observations were made, and signals exchanged with each on four nights.

Time signals were also sent to Natal, Grahamstown, and Port Elizabeth, before and after the Transit; as also to Natal, in conjunction with the operations connecting the longitude of Madagascar with this Observatory.

10. The longitude of Lady Donkin's Monument, Port Elizabeth, has been connected by telegraph with this Observatory, under the direction of H.M. Astronomer, but at the expense of the Government of the Cape Colony. The comparison of this longitude with the results of a trigonometrical connection of the same points, made by Captain Bailey, R.E., 1859–62, gives an arc of 7° 40′ of longitude (the latitudes of the extremities are nearly identical) possessing considerable geodetic interest.

11. *Instrumental Changes.*—A new 6-inch Equatorial by Grubb has been mounted, originally to observe the Transit of *Venus*, but by permission of the Committee it was fitted with micrometric appliances, and was partly employed in the observations of *Victoria* and *Sappho*. The instrument requires considerable alterations, however, to render it a complete or satisfactory instrument for other than star-gazing purposes. Optically it is an admirable instrument.

The old Wind Tower has been altered, a pillar built, and a

Dome erected to receive the 6-inch Equatorial. The whole forms a suitable and convenient Observatory.

The Government of India, on the representation of General Walker, has lent the great 3-foot Theodolite (constructed under the superintendence of Colonel Strange) to H.M. Astronomer for use at the Cape. This instrument has been employed in observing the Great Comet and the Transit of *Venus*, but will be chiefly devoted in future to determining the Declinations of Southern stars by observations of the azimuth of their greatest elongation.

Plans have been prepared for providing new collimators for the Transit Circle, and these so mounted as to permit the independent determination of the horizontal point to North and South, and observation of stars by reflection to 70° Z.D. The plans also include the erection of meridian marks to North and South, viewed by lenses of long focus. The plans are in the hands of Mr. Simms, and it is believed they will be completed about the middle of the current year.

12. The system of time signals has been further extended and improved; a clock controlled from the Observatory is also being erected at the entrance of the Cape Town Docks.

The tidal observations have been begun at East London; those at Table Bay will begin in March of the current year. The tide-gauges for Durban and Port Elizabeth have been received, but are not yet mounted.

The meteorological observations made at the Royal Observatory in the year 1881, together with those made in different parts of the colony, have been printed in the Reports of the Cape Meteorological Commission.

[The above Report arrived too late for insertion in the Annual Report of the Council.]

Errata.

Vol. xliii. p. 134, line 29 from top. *For* $+0''\cdot24$, *read* $-0''\cdot24$.
p. 142, line 22 from top. *For* LL. 1779·39, *read* LL. 1797·39.

Erratum in the Annual Report.

The six lines "He also . . . . Observatory," on pp. 159–60, are out of their place: they belong to the obituary notice of Mr. Walker, on pp. 183–4.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. APRIL 13, 1883. No. 6.

E. J. STONE, M.A., F.R.S., President, in the Chair.

H. J. Chaney, Warden of Standards, Board of Trade, 29 Chalcot Crescent, Regent's Park Road, N.W.;
B. J. Hopkins, 23 Weymouth Terrace, Hackney Road, E.;
Rev. T. Harley, 24 Amwell Street, E.C.;

were balloted for and duly elected Fellows of the Society.

Note on some Criticisms made by Mr. Stone on the Methods available for Determining the Solar Parallax. By David Gill, LL.D., Her Majesty's Astronomer at the Cape of Good Hope.

In the accounts which have appeared in the *Observatory* and the *Astronomical Register* of the interesting discussion which followed Professor Newcomb's remarks at the January meeting of the Society, there are some points raised which appear to deserve further notice.

I refer in particular to the criticisms of the President (Mr. Stone) on the Heliometric method of determining the Solar Parallax. If Mr. Stone is correctly reported, he gives the following criticism of the method:

"When the distance of a planet from two stars, one of greater and the other of less right ascension, is measured E. and W. of the meridian, by comparing the distance of each star from the planet as measured on the two sides of the meridian, we can get a determination of the parallax affected by no systematic errors but corrections for refraction, motion of planet in the interval, and small error due to error of scale over the change of distance measured. The result should, therefore, be an accurate one. But by taking each star we ought to get independent

determinations; and if these agreed very closely, it would prove that any systematic errors must have been reduced to very small limits. When, however, we have made the results from the two stars agree by the supposition of a change of scale value, although the result deduced may be true, yet its truth is not apparent from the equations; the check is lost."

I may ask, in the first place, whether it is fair criticism to condemn a method because the critic supposes it will not bear a test which it was never contemplated to apply to it, which would give no additional weight in the elimination of systematic errors if it were applied, and which would involve a mode of discussion that is obsolete and unscientific.

Let it be supposed that I had applied to my observations of *Mars* the test proposed by Mr. Stone; that I had deduced from measures of the stars preceding and following the planet precisely the same parallax, what additional value would the final result have had? I should simply have proved that, on the whole, a correct value of the temperature coefficient of the Heliometer had been employed. The result would not have proved that the light of the planet was differently influenced by refraction from that of a star, nor would any error have been eliminated that is not eliminated in the method of reduction which I adopted. It is besides infinitely more scientific and exact to proceed by a method of reduction which involves no assumptions as to temperature coefficients, or absolute scale values, but which in itself contains all the data for the elimination of errors that may exist in the determination of these quantities, which, after all, cannot be termed *constants*, for reasons given in my Memoir on the *Mars* Observations (p. 56).

It is perhaps desirable to recall the mistakes of Wichmann in his discussion of the parallax of the Star 1830 Groombridge. These mistakes have been most ably pointed out by Döllen (*Bull. Phys. Math. Acad. St. Petersburg*, t. xiii.) to be due to the adoption of the absolute method advocated by Mr. Stone; and he also shows the truthful conclusions that may be drawn from the same observations by a method similar with that which I have followed. Wichmann himself afterwards frankly acknowledged his error.

It is, in fact, a principle that is now accepted by all refined and accurate observers, that in delicate researches the observations must be so arranged that the possible errors shall take opposite signs, and, as far as possible, eliminate each other.

The point in Mr. Stone's criticism which most surprises me is his statement that the truth of the result for the class of errors taken account of by the equations (for Mr. Stone only discusses these) is not apparent from the equations.

I took especial pains (pp. 116–125 of my *Mars* Memoir) to explain the formation of these equations, and the question of the rigid consideration of all the errors named by Mr. Stone is not a matter of opinion but of geometry. I would be greatly

indebted to Mr. Stone if he would point out where these equations are not geometrically true, at least far within all practical limits.*

Mr. Stone goes on to say, "The method in one case is a very strong one indeed; but in the case of the necessity of supposing different scale values E. and W. of the Meridian, I must confess that I consider its strength problematical."

It seems to have escaped the notice of Mr. Stone that I have anticipated this objection, and at pp. 151–155 of my *Mars* Memoir I have given the results of a reduction in which the scale values E. and W. of the Meridian *are not supposed different but identical.*

The result of this reduction is in precise agreement with the more refined original reduction, and the close agreement of the separate results proves that the systematic differences of scale value E. and W. of the Meridian are confined within very narrow limits.

My contention, however, is that no matter how large the systematic errors of scale value produced by difference of temperature in the evening and morning observations may be, the final results will be entirely independent of such errors if reduced by the method employed in my original reduction. It is surely wiser and safer to assume that such errors may exist, and to employ a method of reduction by which they will be eliminated, than to adopt a crude and exploded method of discussion which ignores the existence of the carefully arranged means of

* There is only one assumption in the formation of the equations which is not rigidly exact—it is, that the relative positions of the comparison stars are assumed known. The effect of this assumption is that the accuracy of the observed change of the planet's R.A. between the evening and morning observations depends to a small extent on the tabular difference of R.A. of the stars of comparison. (I confine myself, for sake of simplicity, to the consideration of one coordinate.) An error in this difference will affect the measured change of the planet's R.A. by the quantity

$$\text{Error of } \Delta\alpha \text{ of comparison stars} \times \frac{\text{observed motion}}{\Delta\alpha \text{ of comparison stars}}.$$

About opposition the greatest change of R.A. between the observations of the evening and following morning appears to be about 300″ of arc, and the comparison stars may be taken as 2° apart, that is, each 1° distant from the planet on opposite sides of it. If we suppose the probable error of the $\Delta\alpha$ of the two comparison stars to be $\pm 0''\cdot25$ (which is a large estimate considering the number and excellence of the meridian observations), the effect of this error on the measured change in the planet's R.A. would be

$$\pm 0''\cdot25 \times \frac{300}{7200} = \pm 0''\cdot01,$$

which would produce an error of less than 0″·003 in the resulting solar parallax! When it is further considered that the final tabular motion of the planet is derived from the adopted star places, it is obvious that not the remotest systematic error can remain from the assumption in question.

eliminating possible errors, and affords no measure of the real accuracy of the final result.

It is of course open for anyone to assert dogmatically that the only crucial check is to determine the parallax separately from the absolute distances measured from stars preceding and following the planet. But let us take a well-known and strictly parallel case to illustrate the fallacy of such an assertion. It is now pretty generally admitted that for field operations (that is, when star places are assumed known) the most accurate method of determining latitude is that known as Talcott's method. This consists in measuring the *difference* of zenith distance of two stars culminating at nearly equal and opposite zenith distances from the place of observation.

A refined observer who desired to determine his latitude with the greatest precision would also be careful to employ as many pairs of stars in which the Z.D. of the North Star exceeded that of the South Star, as pairs in which the Z.D. of the South Star exceeded that of the North Star.

The observer would then be in a position

1. To discuss the resulting latitude, supposing the screw value unknown, and to determine the screw value from the observations;

2. To trust to the general symmetry of the arrangement of the comparison stars for the elimination of any error in the adopted screw value;

3. To deduce the latitude from absolute zenith distances of the stars (which we shall suppose also to have been measured), and to form our estimate of the accuracy of the resulting latitude from the agreement of the absolute results from the North and South Stars separately.

The first of these methods of reduction corresponds with that employed in my original reduction of the *Mars* stars.

The next represents the second discussion to which I have referred, in which the scale value is supposed known, and not to change between the East and West observations.

The third represents the method advocated by Mr. Stone.

If Mr. Stone is consistent he is no less bound to maintain that the check is lost in Talcott's method because the latitude is deduced from the *differences* of the opposite zenith distances, and not from the *absolute* opposite zenith distances; and that the accuracy of the resulting latitude would be more fairly represented by the agreement of the latitudes deduced separately from the absolute altitudes observed N. and S. of the zenith, than from the difference of Z.D. of pairs of opposite stars. He would, in fact, ignore the powerful elimination of errors of flexure and refraction secured by Talcott's method, in the same way that he would ignore the elimination of error of scale value and refraction in the Heliometer method which I have advocated.

If, in fact, Mr. Stone insists on the absolute method in the case of the Heliometer, as opposed to the elegant method of dif-

ference, I do not see how he can avoid insisting on it in case of the Talcott latitude method; and if he does so, it is safe to assert that his opinion will not be seconded by that of any competent living astronomer who has ever made a refined investigation with one instrument or the other.

Mr. Stone's criticism generally does not, however, touch the real weak point of my result obtained from the *Mars* observations. That point is the possibility, and even probability, that the average light of *Mars* is of different refrangibility from that of the average light of the comparison stars, and that on account of the ruddy light of *Mars* it is not impossible that my value of the solar parallax is slightly too great.

Possibly partly to this account, partly to chromatic dispersion, is due the large value of the solar parallax that has been obtained from meridian observations of *Mars*. We have no data by which to estimate how far it is possible there should exist, besides, a systematic error in measuring zenith distances, having the same sign for nearly all observers. There are not wanting instances of similar nearly universal errors—errors whose common sign may be attributed to the fact that all the observers are human beings more or less similarly constituted.

Thus in determining the personal equation of the Cape observers for stars of different declination, I found that there was a marked difference in the relative equations on opposite sides of the zenith. Accordingly, a number of zenith stars were observed in which each star was observed over the first two or three wires, with the observer's feet to the South, and over the last two or three wires with his feet to the North. In observing the next star the order was reversed, in order to eliminate errors of the wire intervals.

The following are the results so obtained; each result depends on the observations of a different night:—

		No. of Stars.	Mean.
	s		s
Finlay	= +0·063 ± ·017	21	
	+ ·079 ± ·011	32	+0·079
	+ ·111 ± ·025	16	
	+ ·078 ± ·012	28	
Maclear	= +0·145 ± ·025	23	
	+ ·117 ± ·017	23	+0·122
	+ ·112 ± ·023	20	
	+ ·115 ± ·019	24	
Pett	= +0·056 ± ·020	18	
	+ ·009 ± ·019	16	+0·015
	− ·023 ± ·021	22	
	+ ·016 ± ·018	24	

		No. of Stars.	Mean.
	s		s
Freeman =	+0·014 ± ·030	24	+0·066
	+ ·076 ± ·018	11	
	+ ·144 ± ·027	23	
	+ ·029 ± ·022	17	

These results are taken out in the sense: clock slow, observer facing N.; clock slow, observer facing S.*

Precisely similar results were afterwards obtained by the use of a reversing prism attached to the eyepiece, by turning which through 90° the star could be made to appear to move either from right to left or left to right.

Here, then, is a very marked error, having the same sign, common to all our four experienced observers.

Again, in the case of the meridian observations of the *Mars* stars, it was found that nearly all observers made the Right Ascension of the final stars too great.

Is it not possible, in face of these facts, that in observing zenith distances of a large and unsymmetrically-coloured disc like *Mars*, when viewed at a considerable zenith distance, there may be a very sensible systematic error, having the same sign for nearly all observers?

We have at least no proof to the contrary, and my friend Dr. Elkin has suggested a very admirable test. If *Mars* were observed at Northern and Southern observatories at an opposition when the planet is nearly as distant as possible from the Earth, and if such a systematic error as I have suggested really existed, then the parallax resulting from such observations should be still larger than that derived from the oppositions when *Mars* is near the Earth.

There are excellent opportunities for making such determinations in 1884 and 1886.

There is, however, one method of determining the solar parallax which I believe to be free from all systematic error. I refer to the method which I followed in the case of *Juno*. These observations were confessedly incomplete, and afford, in themselves, no crucial test of the method.

There is a test, however, which fortunately depends on no theoretical considerations, to which I believe no exception can be taken, and which is capable of being easily applied.

Anyone who has taken part in the recent measures of *Victoria* and *Sappho* will admit that it is impossible to distinguish between the appearance of either of these planets and that of a fixed star of similar brightness. It is, therefore, possible to test the method by employing a fixed star instead of a planet. We

* These results may help to explain the systematic discordances which Dr. de Ball has found between the Right Ascensions of the Cape and Northern Catalogues.

know that a fixed star has no sensible diurnal parallax, and therefore we may measure with the Heliometer its distance from two or more fixed stars, and determine whether there is any apparent change in the relative position of this star with respect to its neighbours, as the result of a series of measures made both East and West of the Meridian.

As an example of such a test, I give the results of my last measures of the kind.

The circumstances are far from the most favourable possible. The central star (*Sirius*) is not in the line between the comparison stars *a* and *b*, the angle at *Sirius* being 165°. Also East of the Meridian the stars are nearly horizontal, and West of the Meridian they are nearly vertical.

The circumstances of definition were not favourable, the images and steadiness being 2–3 (where 1 is the most favourable, and 3–4 the worst in which such measures can be attempted). The light of the bright star was reduced by wire gauze screens which make the image of *Sirius*, as seen in the Heliometer, quite similar in brightness and appearance to the 7th magnitude stars of comparison.

1882, *December* 24.

Evening Observations.

S. Time.	Sirius and *a*	Refrac.			Sirius and *b*	Refrac.	
h m	″	″	″	h m	″	″	″
2 38·2	3683·854	1·287	3685·14	2 46·9	3627·088	1·029	3628·12
3 15·6	84·497	1·184	·68	3 0·2	26·907	1·016	27·92
3 23·6	83·995	1·145	·14	3 32·7	27·075	1·016	28·09
3 57·2	84·240	1·094	·33	3 38·8	27·062	1·029	28·09

Morning Observations.

9 18·8	3683·069	1·763	3684·83	9 28·8	3626·200	1·673	3627·87
9 55·2	82·721	2·200	84·92	9 46·7	·071	1·853	27·92
10 3·2	83·172	2·354	85·53	10 13·4	25·556	2·213	27·77
10 32·4	82·155	3·088	85·24	10 22·1	25·724	2·380	28·10

These observations give in the mean

	Sirius and *a*		Sirius and *b*		*a*—*b*
	h m	″	h m	″	″
Evening observations	3 18·7	3685·32	3 14·7	3628·05	57·27
Morning „	9 57·4	·13	9 57·8	27·93	57·20

Each separate result is the mean of two bisections, one in each position of the segments with respect to the zero point.

The four results for each star on each occasion form a com-

plete set in which every variation of the possible methods of bisection is represented, both as to the final direction of the motion by which the bisection is completed and with reversal of the Heliometer on its axis of rotation. These conditions are of course unfavourable to the apparent agreement of the separate results, but very favourable to the accuracy of the mean.

The very exact agreement in the value of $a-b$ from the evening and morning observations is of course, to some extent, a matter of chance. From the discussion of a very large number of similar observations, which will soon be ready for the press, the probable error of the difference $(a-b)$ comes out $\pm 0''\cdot 15$ for eight bisections of each star, made in the order and with the precautions above described, and the same observations agree in showing that the resulting measure of $a-b$ is quite the same, whether measured East or West of the Meridian.

Now, if instead of *Sirius* we had a minor planet, and if a station were occupied near the Equator, and comparison stars employed of nearly the same declination with the planet, and on opposite sides of it, and the declination were small, this distance $a-b$ would represent twice the parallax due to the altitude. That is, the difference between $a-b$ in the evening and morning after allowing for the planet's motion would be *four* times the parallax at the adopted altitude of observation.

Put this altitude even so high as 45°, and we get for the probable error of the solar parallax from one night's observation

$$\pm 0''\cdot 15\sqrt{2} \times \frac{\Delta\sqrt{2}}{4} = \pm 0''\cdot 15\Delta,$$

where Δ is the planet's distance from the Earth, that of the Earth from the Sun being unity.

If planets as favourable as *Victoria* and *Sappho* were observed, this would reduce the probable error of the determination of the solar parallax to

$$\pm 0''\cdot 12.$$

as the result of a single night's measures.

The method is not liable to the smallest uncertainty, if the instrument and observer have been first proved by the tests I have indicated. It is certain that from the observation of the oppositions of two or three minor planets by this plan an entirely reliable value of the solar parallax could be obtained, and that at a cost of one-fourth of the last British Transit of *Venus* rate, including the cost of a new Heliometer, which would afterwards be available for other researches.

I have added the latter part of these notes in answer to Mr. Stone's expression of his opinion "that none of our methods (for determining the solar parallax) can be considered as free from the

suspicion of systematic errors." It would be of great interest if Mr. Stone would point out his objections to the method I have described and to the tests I have proposed.

Royal Observatory,
Cape of Good Hope:
1883, *March* 6.

On the Position of λ *Ursæ Minoris.* By John Tatlock, Jun.

(*Communicated by Prof. T. H. Safford.*)

The present paper is intended as a continuation of the paper published under the same title by Prof. T. H. Safford in the *Monthly Notices* for June 1878.

This paper takes up the subject where Prof. Safford left off, and has been prepared, under his direction, according to the method and formulæ given by him in Vol. IV., Part 1, of the Annals of the Observatory of Harvard College, where he has given a similar discussion of this star, based on the data accessible in 1862.

The method given in the foregoing publication, and used in this discussion, is as follows: Let η be the correction to the assumed A.R. for 1855·0; η' the correction for n years to the assumed proper motion in A.R.; i the correction to the assumed Dec. for 1855·0; and i' the correction for n years to the assumed proper motion in Dec. In this discussion we have assumed $n=30$.

Also let α' and δ' be the star's A.R. and Dec. for the time $t+1855$, referred to the coordinate planes of 1855, δ the star's Dec. at the time t referred to the planes of 1855, ξ the angle at the star, used in referring the proper motion for 1855 to the planes of $t+1855$, and ω and ω' the weight in A.R. and Dec. respectively. Now making

$$\frac{\eta}{15}=w,\ \frac{\eta'}{15}=x,\ i=y,\ i'=z,$$

and also in A.R.,

$$a=\sqrt{\omega}\ 15\cos\delta\cos\xi$$

$$b=a\ \frac{t-1855}{30}$$

$$c=\sqrt{\omega}\sin\xi$$

$$d=c\ \frac{t-1855}{30}$$

$$v=\sqrt{\omega}\ \Delta\alpha'\cos\delta',$$

and in Dec.,

$$15 \cos \delta \sin \xi$$

$$\frac{-1855}{30}$$

$$\cos \xi$$

$$\frac{-1855}{30}$$

$$\Delta\delta' \ (c-o),$$

the equation of condition as

$$+cy+dz$$

paper in the *Monthly Notices* he has values of $\Delta\alpha' \cos \delta'$ and $\Delta\delta'$ as derived at investigations of others. In the present have been verified by reference to the In one or two cases the authorities paper have been replaced by a newer or For instance, Auwers's reduction of instead of the value given in Prof. Saf- 1875 has been substituted for Rogers paper.

equations have sometimes been formed by results for two or more years, notably in and Radcliffe Catalogues. In all motion from the epoch of the Catalogue the "observed" place has been applied. table gives the values of $\Delta\alpha' \cos \delta'$ and $\Delta\delta'$, in addition to the values given in Prof.

	$\Delta\alpha' \cos \delta'$	$\Delta\delta'$	Weights
...	$+0.09$	-1.26	1, 1
...	-0.15		1
...	$+0.16$	$+0.02$	2, 2
...	-0.21	$+0.62$	1, 1
...	-0.64	$+0.29$	½, 4
...	$+0.15$	-0.35	3, 2
...	$+0.06$	-0.12	3, 4
...	$+0.22$	-0.04	3, 4

equations of condition, 56 in number, squares, we find the following system of

$$6{\cdot}5768w - 0{\cdot}9431x - 0{\cdot}0050y + 0{\cdot}2427z + 0{\cdot}2280 = 0$$
$$-0{\cdot}9431w + 3{\cdot}5262x + 0{\cdot}2552y - 0{\cdot}0990z - 0{\cdot}4326 = 0$$
$$-0{\cdot}0050w + 0{\cdot}2552x + 89{\cdot}5932y - 6{\cdot}0503z + 8{\cdot}4199 = 0$$
$$0{\cdot}2427w - 0{\cdot}0990x - 6{\cdot}0503y + 37{\cdot}1541z - 1{\cdot}1937 = 0$$

The final equations are

$$w - 0{\cdot}1434x - 0{\cdot}0008y + 0{\cdot}0369z + 0{\cdot}0347 = 0$$
$$x + 0{\cdot}0750y - 0{\cdot}0189z - 0{\cdot}1179 = 0$$
$$y - 0{\cdot}0675z + 0{\cdot}0940 = 0$$
$$z - 0{\cdot}0175 = 0$$

The solution of which gives the following values of the unknown quantities.

$$w = -0^{s}{\cdot}017$$
$$x = +0{\cdot}124$$
$$y = -0''{\cdot}083$$
$$z = +0{\cdot}018$$

The assumed position for 1855·0 is $\alpha = 20^{h}\ 8^{m}\ 30^{s}{\cdot}200$ and $\delta = 88^{\circ}\ 52'\ 32''{\cdot}30$, and the values of the proper motion are $-0^{s}{\cdot}073$ and $+0''{\cdot}01$ in A.R. and Dec. respectively. Applying the corrections which we have found, the corrected places for 1855·0 are

$$\alpha = 20^{h}\ 8^{m}\ 30^{s}{\cdot}183$$
$$\delta = 88^{\circ}\ 52'\ 32''{\cdot}22$$

And the corrected values of the proper motion are, in A.R.,

$$-0^{s}{\cdot}069;$$

in Dec.,

$$+0''{\cdot}0106$$

From these elements the position for 1885·0, without proper motion, is

$$\alpha = 19^{h}\ 38^{m}\ 57^{s}{\cdot}705$$
$$\delta = 88^{\circ}\ 57'\ 19''{\cdot}34$$

And the amount of proper motion is

$$\Delta\alpha = -2^{s}{\cdot}365$$
$$\Delta\delta = +0''{\cdot}233$$

Hence the position for 1885·0 is

$$\alpha = 19^{h}\ 38^{m}\ 55^{s}{\cdot}340$$
$$\delta = 88^{\circ}\ 57'\ 19''{\cdot}57$$

Dr. Auwers gives for the same epoch,

$$\alpha = 19^{h}\ 38^{m}\ 55^{s}{\cdot}704$$
$$\delta = 88^{\circ}\ 57'\ 19''{\cdot}46$$

Field Memorial Observatory, Williams College,
Williamstown, Mass., U.S.A.:
1883, *Feb.* 21.

Measures of the Companion to Sirius. By S. W. Burnham.

My measures of the companion to *Sirius*, made on ten nights during the present season with the 18½-in. Refractor of the Dearborn Observatory, are as follows:—

	°	"
1882·988	40·6	9·16
83·000	40·3	9·27
83·074	41·1	8·99
83·107	39·9	9·02
83·115	39·8	9·17
83·134	40·1	8·90
83·137	38·1	9·17
83·151	41·0	8·92
83·153	40·6	8·91
83·159	39·6	8·86
Mean = 1883·10	40·1	9·05

Chicago:
1883, *March* 30.

Observations of Comet c, 1881 (*Schäberle*), *made at the Cambridge Observatory with the Northumberland Equatorial and Square-bar Micrometer.*

(*Communicated by Prof. J. C. Adams, M.A., F.R.S.*)

Green. M.T.	Aberration Time.	App. R.A.	Parallax.	App. Decl.	Parallax.	Comp. Star.	No. of Comp.
1881.		h m s	s	° ' "	"		
Aug. 24·35221	−·00332	11 59 49·113	+0·782	+37 19 33·28	+10·67	*a*	3
24·37579	−·00332	12 0 12·808	0·752	37 14 52·32	11·49	*a*	5
26·34636	−·00335	12 30 21·228	0·729	30 38 14·45	10·58	*b*	7
26·36421	−·00336	12 30 36·054	0·720	30 34 25·38	11·12	*b*	6
,,	,,	36·027	,,	24·77		*c*	6
27·37251	−·00339	12 43 46·641	0·686	27 4 55·38	11·30	*d*	11

Assumed Mean Places for 1881·0 of Stars compared with Comet c, 1881 (*Schäberle*), *with Reductions to Apparent Places for the night of Observation.*

	Right Ascension.	Reduc.	Declination.	Reduc.	Authority.
	h m s	s	° ′ ″	″	h
a	12 0 36·610	+1·576	+37 26 53·40	−8·45	Bessel (W₂) 11–1170, 71
b	12 30 5·613	1·701	30 35 0·37	−7·73	„ 12–614, 15
c	12 27 36·592	1·699	30 41 48·71	−7·85	„ 12–554
d	12 43 58·904	1·770	27 4 51·51	−7·49	Cambridge Zones, April 30, May 11.

On Mr. Finlay's Pre-Perihelion Observations of the Great Comet (b) 1882.

(*Communicated by H.M. Astronomer at the Cape.*)

The following are the results of the observations obtained by Mr. Finlay on the morning on which he first saw the comet, and on the following morning. They are, I believe, the earliest exact observations of this remarkable body.

The observations were made with the filar micrometer of the 6-in. Equatorial. The results are corrected for refraction.

Cape M. T.	Right Ascension.	No. of Obs.	N.P.D.	No. of Obs.
d h m s	h m s			
Sept. 7 17 23 15·7	9 31 44·54−·054*p*	14		
7 17 26 5·3			° ′ ″ 90 59 49·3+·551*p*	8
8 17 20 10·5	9 40 2·14−·054*p*	5		
8 17 27 16·7			90 56 22·8+·552*p*	5

The following are mean places of the stars of comparison, derived from recent observations with the Transit Circle:—

		R.A. 1882·0.	Corr.	N.P.D. 1882·0.	Corr.
	°	h m s	s	° ′ ″	″
For Sept. 7 Arg.	−0·2229	9 32 11·78	+1·82	90 56 40·57	+10·71
8 „	−0·2256	9 44 23·16	+1·82	90 52 18·46	+11·13

The mean places are for 1882·0; the corrections are to the apparent place on dates of observation.

Note on the Nucleus of the Great Comet (b) 1882. By David Gill, LL.D., H.M. Astronomer at the Cape of Good Hope.

(*Extract from a letter to Mr. Knobel.*)

In reply to the question which you ask on behalf of the Society, viz. Whether before perihelion the Great Comet of 1882 showed a duplex or compound nucleus, the observations recorded

by Mr. Finlay and Dr. Elkin on September 7 and 8, and printed in the *Monthly Notices*, vol. xliii. p. 21, prove clearly that no duplicity could be detected with our optical means on these dates. Dr. Elkin describes the nucleus as a sharp, well-defined disk 10″ or 15″ in diameter and strongly condensed in the centre.

A short glimpse which I obtained between clouds on September 9 confirmed this view. The weather was unfavourable till the 17th (the day on which the disappearance of the comet at the Sun's limb was noted). The nucleus was certainly single on that day; half an hour before the disappearance of the comet it was measured by Mr. Finlay as 4″ in diameter.

The day following perihelion passage the comet was observed by myself with the Transit Circle. The nucleus was then undoubtedly single, and certainly rather under than over 4″ in diameter; in fact, as I have described it, it resembled very much a star of the 1st magnitude seen by daylight.

Mr. Finlay and Dr. Elkin made careful drawings on the 17th, and I made one on September 18, and we have a continuous series of drawings of the comet down to September 28, which prove that within the limits of our optical means the nucleus was single till that day inclusive.

The morning of September 29 was clouded.

On September 30 Mr. Finlay remarks in his note-book, "There seem to be two balls of light in the head." Dr. Elkin, with the Heliometer and low power, noted on the same morning that the nucleus was elongated.

On October 1 Mr. Finlay's sketch shows that the balls of light (as he calls them) were farther apart, but conected by a line of light.

On October 9 Mr. Finlay noted that there were several points of condensation in the nucleus; of these the two extreme points were brightest. These differed 1½ second in R.A.

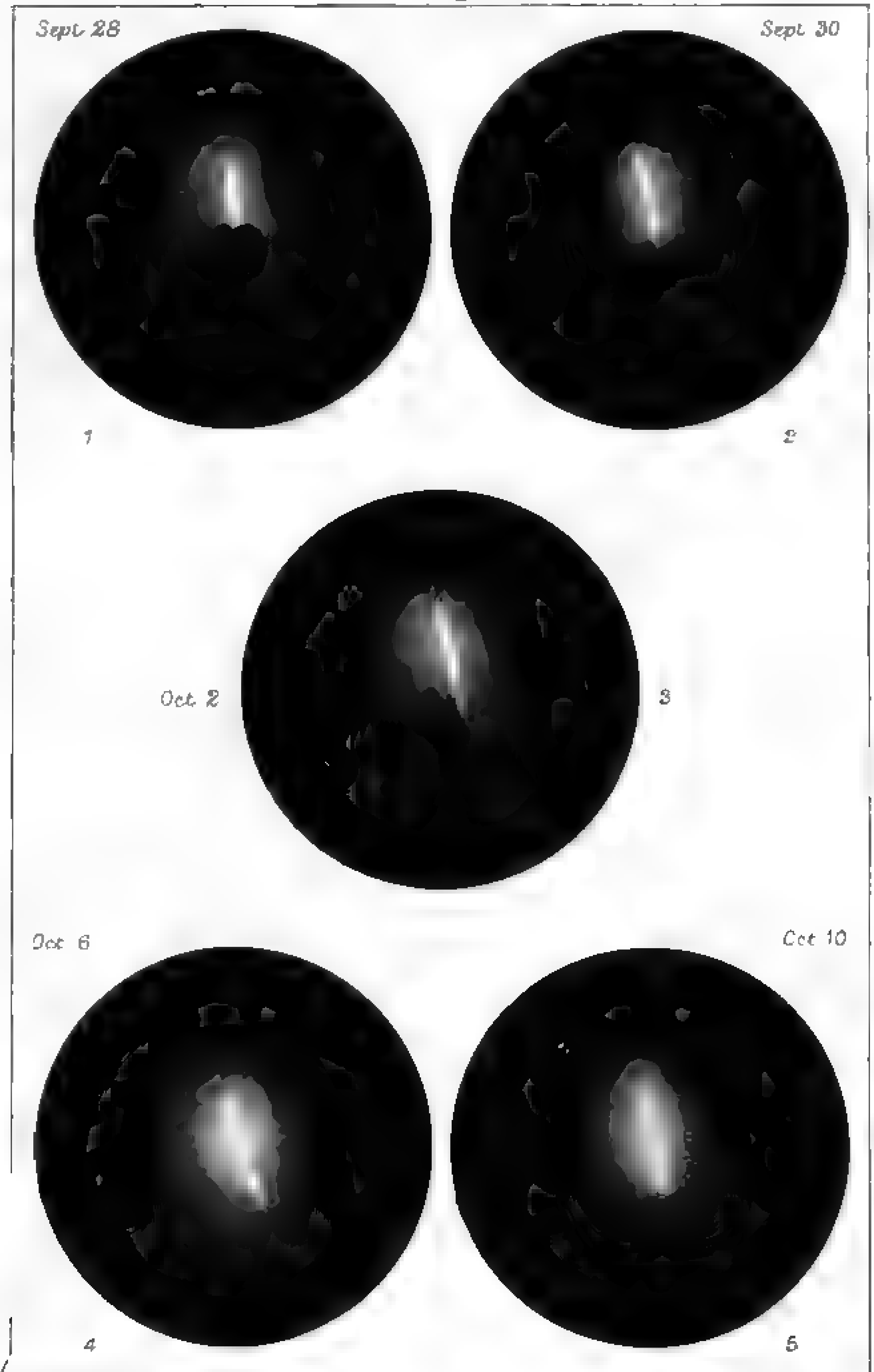
On October 10 several bright points were noted, the middle ones slightly south of the line joining the extreme ends.

On October 12 Mr. Finlay makes the line of nuclei 39″ in length.

On October 17 I counted 5 points of condensation in a pale cigar-shaped nucleus, which, in a popular paper communicated to the Cape *Quarterly Review* (a copy of which I send), I have described as a narrow line fully a minute of arc in length, with five little nuclei from 2″ to 3″ of arc in diameter, looking like very small beads strung on a thread of worsted. But to realise this description it is necessary to suppose the beads to have very large holes, and the worsted to be fluffy, so as to swell out and meet round the beads.

On November 1 Mr. Finlay found the nucleus (or line of condensation) to measure 3½ seconds of time in R.A., and that it had become much more indistinct.

COMET b 1882



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Wm Newman & Co imp

Drawn by Major G E Strahan, R E
at Mussooree, India

Last night (March 6), though the comet is a conspicuous object in a good opera-glass, the nucleus, or head, is faint in the extreme, most difficult to observe in R.A., and liable to large personal error in observing. It is an ellipse of which the major and minor axes are about $3\frac{1}{2}'$ and $1\frac{1}{2}'$ respectively. It is now diminishing in apparent size; it seems to have attained its maximum apparent size in December.

The places of the comet obtained here depend from September 30 to November 23 on measures made to the following extremity of the nucleus, because till the latter date there was a distinctly brighter condensation towards that point. Previous to November 23 observations were made both with the Heliometer and the Equatorial. After November 23 observations were confined to the Equatorial, and it was also found necessary to observe the centre instead of the extremity of the nucleus.

The necessary data for reduction to any desired point of the nucleus are, however, available. But until it is possible to publish the drawings of the nucleus I am convinced that no satisfactory account of the changes in the nucleus or discussion of the orbit of the comet can be made, and on this account I do not propose to publish the Cape observations until the necessary drawings are published at the same time.

Note on Sketches of the Great Comet (b), 1882. By Major G. Strahan, R.E.

I send herewith a few sketches of the comet of last September, with the hope that they may be of interest to the Fellows of the Society who may not have been favoured with such clear skies as I was at Mussooree (at an altitude of 6700 feet), in the North-West Provinces of India. I had intended making a much longer series of them, but the changes in the comet's appearance after Oct. 10 were so trifling as to make it hardly worth while. The instrument used was a Browning-With Reflector, with an aperture of $8\frac{3}{4}$ inches, and power of 160. Unfortunately I had no micrometer available; the dimensions are, therefore, merely estimations.

Calcutta:
1882, *Dec.* 1.

Note on Drawings of the Great Comet (b), 1882, *made at the Observatory, Arcetri, Florence.* By Wilhelm Tempel.

Continued ill-health and an almost uniformly cloudy sky greatly interfered with my observations of the comet of September, and I was able to make but few sketches of it.

The accompanying sheet of drawings was destined for the Royal Astronomical Society, but I have hesitated about sending it, as it is merely the work of my own hand, with the assistance of the telescopes of the Observatory here; and it would appear that of late much greater value is attached to photographic representations. I trust that the Society will kindly receive this work of mine, and not criticise it harshly.

As these sketches were made as faithfully as possible from nature, any explanation of them would be superfluous, for, as Father Secchi has well said, "Le figure dicono più che molte parole."

The drawing H, however, requires a short explanation, as it has no connection with the comet. It represents two fine threads of glass crossing the focus of an eyepiece. These threads are tubular, and present the appearance of two black lines separated by a single white one. In the figure H the two threads A and B differ in diameter, $A = \frac{3}{1000}$, $B = \frac{12}{1000}$ of an inch.

It is well known that most great comets show a dark line in the middle of the tail; this is seen most plainly in the axis of the tail near the head. The great comet of September also, in the beginning of October, clearly showed this dark line, and the second tail, pointing towards the Sun, had also the appearance of a tube—that is to say, the sides were bright and nebulous, while the axial line was dark.

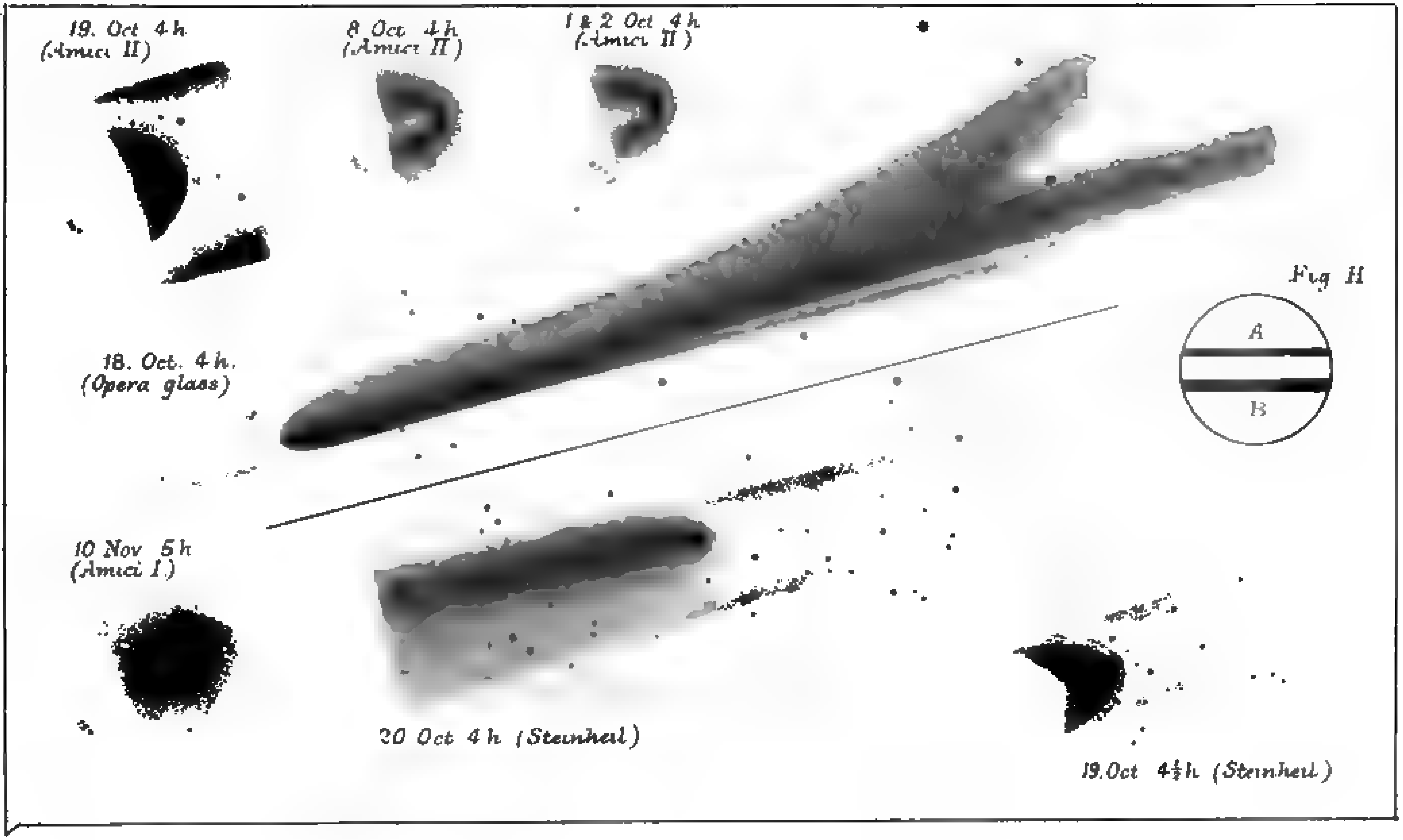
The appearance of the comet's tail presents an evident resemblance to these glass threads. Still, I offer no hypothesis, simply remarking that it is the duty of every observer to seek for familiar forms to compare with such as are difficult of comprehension.

The position-angle of the second nucleus of the comet with the axis of the tail, as given in the drawing, is only an estimation, not having been measured.

Arcetri, Florence:
1882, *December.*

Notes on the Great Comet (b) 1882. By E. E. Markwick.

I forward a condensed account of my observations of the Great Comet. I was only able to secure one observation of it before perihelion, and this was on September 14, at Durban. When first seen, about 5^h a.m., it was about $5°$ above the horizon, and it appeared ruddy, probably through haze. I looked at it



Drawings of the great Comet (b) 1882.

W. H. Wesley lith.
West, Newman & Co. imp.

through a small achromatic of $1\frac{3}{4}$-in. aperture, which showed the head of a woolly texture. The comet remained visible till nearly sunrise.

On September 18 I looked very carefully for it, but doubtless its proximity to the Sun prevented its being seen.

From the following date the observations were made at Pietermaritzburg with a $2\frac{3}{4}$-in. achromatic, powers 45 to 140.

September 25, $16^h\ 30^m$.—Saw the comet. It was a most magnificent object, with a superb tail many degrees in length. When first seen its head was below the horizon, and it presented an astonishing appearance, like a long white cloud on the horizon. It gradually rose and displayed itself as a lovely sight. The head was pointed, with a bright nucleus, the general tint a soft white. The tail lay nearly in the ecliptic, or parallel to it. The S. edge of the tail was sharply defined, the N. edge softened off. There was a dark streak or shading down the tail, rather towards the S. edge. In the telescope the nucleus was bright and star-like. Watched it till $17^h\ 30^m$, when the nucleus and a little of the head were still visible.

September 30, $16^h\ 45^m$.—Noted the tail as markedly curved. The comet was one of the most exquisite sights I have ever witnessed, seen in a very pure sky. The head was brilliant, and equal to a 1st magnitude star, but the light was more diffused than that of *Jupiter*. The glass did not reveal much, except that the nucleus was an elongated patch of light, the direction of its length not coinciding with the axis of the comet. The finest feature (only seen with the naked eye) was a delicate outlying border, looking like thin gauze or spray, which started back from the head and formed the borders of the tail for some way back. The effect of this was most beautiful.

October 1, between 16^h and 17^h.—Position of head estimated roughly at R.A. $10^h\ 46^m$; S. Dec. 8°; breadth of tail at widest part, $1\frac{3}{4}°$; length, $12\frac{1}{2}°$. Many stars seen through the tail, and these shone quite brightly. There was still the pronounced dark streak in the tail, and further I fancied I could see traces of other streaks. The same delicate halo surrounded the head and sides of the comet proper. In the telescope, by quickly moving it backwards and forwards, this delicate light could be seen in advance of the nucleus.

October 4, 16^h.—Tail appears a little longer, although possibly not quite so bright. The streak was barely visible; some hazy light round the head. The nucleus appeared woolly in the telescope, and the hazy envelope could be seen $1\frac{1}{2}°$ in advance of the nucleus. The tail, if produced, would pass almost centrally over *α Hydræ*. Position at $16^h\ 30^m$: R.A. $10^h\ 38^m$; S. Dec. 8° 48′; length of tail, 14°. This and the following positions were obtained by comparing comet with stars near its course, the *Uranometria Argentina* forming a most excellent and trustworthy guide, as it appears to represent the heavens with the utmost fidelity. South, preceding the comet's head, at this

time were seen, about $1\frac{1}{2}°$ distant, two wisps or pieces of nebulous-looking light. Whether they had anything to do with the comet I cannot say; but I can trace no nebula as being in this position, and moreover I have not been able since to recover them.

October 5, $15^h\ 30^m$.—General features of comet unchanged. No streak was seen, and the end of the tail seemed rather ragged. Direction of tail towards *α Hydræ*. Position at 16^h: R.A. $10^h\ 32^m\ 53^s$; S. Dec. 9° 24′.

October 9, $15^h\ 20^m$.—S. edge sharp. The end of the tail and its N. edge very much softened off; in fact the S. edge seemed to project at the end into a sort of wisp. Position at $15^h\ 30^m$: R.A. $10^h\ 27^m$; S. Dec. 11° 14′. I noticed that a star near *λ Hydræ*, over which the tail passed, was invisible to the naked eye. Nucleus elongated and inclined at an angle to axis of comet. Faint halo round head seen, with naked eye, quite 1° in advance of nucleus.

October 10.—Comet well seen in a very clear sky from $15^h\ 40^m$ to $16^h\ 20^m$. S. edge of tail just grazed *λ Hydræ*. Tail extended to beyond *α Hydræ*. Halo visible in advance of nucleus some 2°. Length of tail 18°, not including nebulosity in front of head. Position at 16^h: R.A. $10^h\ 21^m\ 24^s$; S. Dec. 11° 22′.

October 11, $15^h\ 30^m$.—*λ Hydræ* just within the tail, shining brightly—a very pretty sight. Comet white and silvery. One or two double stars in and near tail, a brilliant spectacle. Halo visible 2° in advance of nucleus; length of tail 17°. Position at $15^h\ 30^m$: R.A. $10^h\ 24^m\ 27^s$; S. Dec. 11° 45′.

October 15, $14^h\ 45^m$.—Very clear sky. Saw a bright red meteor near head. Comet's light a little fainter I think generally. Tail of a whitish, silvery light, very broad at end; a wisp projected at the end beyond the other part. Delicate halo round the head and streaming back by the sides. Position from three small stars near; at $15^h\ 15^m$: R.A. $10^h\ 17^m\ 49^s$; S. Dec. 13° 19′.

October 23, $15^h\ 45^m$ to $16^h\ 15^m$.—Light palpably fainter, yet comet is still a superb object, head being as bright as a 1st magnitude star. Nucleus rather better defined than before. It looks like a line of light, the same being inclined at an angle to the axis of the comet. There were a star and a double star a little way from the head, forming a beautiful sight. A faint telescopic star of about 9th magnitude close to nucleus n. f. Traces of dark streak down the tail. Position at 16^h: R.A. $10^h\ 7^m\ 28^s$; S. Dec. 16° 44′; length of tail 18°.

November 2, $13^h\ 30^m$.—Comet still well seen, although very much fainter; moreover, it was dimmed by an old moon not very far off. Position at $14^h\ 25^m$: R.A. $9^h\ 52^m\ 57^s$; S. Dec. 20° 9′; length of tail, 19° 30′; breadth at end about $3\frac{1}{2}°$. It extended to a star No. 60 of *Hydra* (in *Uranometria Argentina*).

November 9, $12^h\ 30^m$.—Perhaps faint traces of a dark streak. Tail wider; two stars, 141 and 160 in *Hydra*, neatly enclosed

it; *i.e.* were lying one on each edge of the tail. Head made a pretty combination with two stars, 174 and 175 *Hydræ*. Nucleus as seen in telescope a dim woolly ball, no bright line as before. Position at $13^h\ 7^m$: R.A. $9^h\ 40^m\ 53^s$; S. Dec. 22° 44′; length of tail, 20°; breadth at end, 3½°.

November 12.—Light very delicately graduated from head to tail. Head is now about equal to a 5th magnitude star in brightness. The head reminded me of the bright nebula near the Nubecula Minor. Position at $13^h\ 22^m$: R.A. $9^h\ 34^m\ 47^s$; S. Dec. 23° 45′; length of tail, 19°; breadth at end about 5°.

November 20, $14^h\ 30^m$ to $17^h\ 40^m$.—Comet generally brighter, I think, than when last seen, close to a 5th magnitude star, to which it was superior in brightness. Observations very much hindered by clouds. I compared its place with θ *Pyxis*. Position at $15^h\ 23^m$: R.A. $9^h\ 16^m\ 54^s$; S. Dec. 26° 0′.

November 30, 15^h.—Comet almost in the zenith. Light much obscured by moonlight, yet there was a long tail visible, and head was as bright as a 5th magnitude star. In telescope head was woolly, and tail barely discernible. Comparing it with 42 *Pyxis* I got position at $15^h\ 21^m$: R.A. $8^h\ 50^m\ 8^s$; S. Dec. 28° 42′; length of tail, 15°; breadth at end, 4½°.

December 8, 11^h.—Very much fainter. Head looks like a diffused nebula in telescope, with no sign of nucleus. Tail faint, but wide; traced to about R.A. $8^h\ 0^m$; S. Dec. 20°; length 8°. No star near for comparison. I estimate position roughly at $11^h\ 15^m$: R.A. $8^h\ 28^m$; S. Dec. 29° 30′.

December 10, $10^h\ 15^m$.—Very clear sky. Tail straight, and extending for some 12°. Position roughly estimated at $10^h\ 15^m$: R.A. $8^h\ 22^m$; S. Dec. 30° 21′.

December 15, $14^h\ 30^m$.—Comet near the zenith. At times it was very clear during observations, and the tail could still be seen of very considerable length and breadth. Position: R.A. $8^h\ 4^m$; S. Dec. 30° 40′; length of tail about 15°; width at end 5°. Tail faded away very gradually, so that it is difficult to say exactly where it terminated. It was directed towards a point: R.A. $7^h\ 40^m$; S. Dec. 20° 0′.

December 22, $12^h\ 30^m$.—Comet very dim owing to bright moonlight. No tail could be seen. The following position was roughly estimated: R.A. $7^h\ 37^m$; S. Dec. 30° 0′.

Observations of Comet a, 1883 (Brooks-Swift), made at the Cambridge Observatory, with the Northumberland Equatorial and Square-bar Micrometer.

(*Communicated by Prof. J. C. Adams, M.A., F.R.S.*)

Green. M. T.		Aberration Time.	App. R.A.	Parallax.	App. Decl.	Parallax.	Comp. Star.	No. of Comp.
1883.			h m s	s	° ′ ″	″		
Mar.	3·29997	−·00666	0 12 23·663	+0·371	+32 0 47·27	+4·97	*a*	5
	3·32017	−·00666	0 12 34·891	0·371	32 0 48·25	5·29	*a*	5
	5·29434	−·00670	0 31 27·105	0·366	31 59 49·00	4·74	*b*	5
	5·30642	−·00670	0 31 33·276	0·369	31 59 50·75	4·93	*c*	5
	8·29263	−·00679	0 59 18·430	0·353	31 35 58·33	4·50	*d*	5
	,,	,,	17·352	,,	56·86	,,	*e*	5
	8·30639	−·00679	0 59 26·352	0·359	31 35 49·36	4·71	*d*	5
	,,	,,	25·475	,,	48·65	,,	*e*	5
	9·30323	−·00684	1 8 23·237	0·354	31 22 22·57	4·60	*f*	5
	,,	,,	23·380	,,	26·03	,,	*g*	5
	9·35984	−·00684	1 8 53·118	0·355	31 21 35·37	5·44	*f*	5
	,,	,,	53·183	,,	37·65	,,	*g*	5
	15·31233	−·00719	1 58 8·749	0·325	29 18 10·06	4·37	*h*	5
	,,	,,	*i*−2 2·784	,,	*i*−0 10·32	,,	*i*	5
	15·33099	−·00719	1 58 17·470	0·332	29 17 39·65	4·63	*h*	5
	,,	,,	*i*−1 54·187	,,	*i*−0 39·91	,,	*i*	5
	30·35196	−·00861	*j*+1 22·438	0·261	*j*−14 55·13	4·17	*j*	5
	,,	,,	3 28 52·526	,,	21 52 56·93	,,	*k*	5
	30·37434	−·00861	*j*+1 28·132	0·263	*j*−15 36·04	4·36	*j*	5
	,,	,,	3 28 58·244	,,	21 52 13·08	,,	*k*	5
	31·33700	−·00871	3 33 24·781	0·252	21 23 47·29	4·01	*l*	5
	,,	,,	24·968	,,	47·13	,,	*m*	5
	31·35294	−·00872	3 33 29·308	0·257	21 23 20·72	4·14	*l*	5
	,,	,,	29·640	,,	15·27	,,	*m*	5
Apr.	2·35507	−·00894	3 42 16·827	0·249	20 24 55·87	4·08	*n*	5
	,,	,,	*o*+1 32·089	,,	*o*+8 59·35	,,	*o*	5
	2·36968	−·00894	3 42 20·748	0·251	20 24 27·76	4·20	*p*	5
	,,	,,	*o*+1 36·301	,,	*o*+8 35·11	,,	*o*	5
	7·34322	−·00959	*q*−1 21·347	0·226	*q*−3 41·35	3·80	*q*	5
	,,		4 2 5·764	,,	18 6 11·58	,,	*r*	5

Assumed Mean Places for 1883·0 *of Stars compared with Comet* a, 1883 (*Brooks-Swift*), *with Reductions to Apparent Places for the night of Observation.*

	Right Ascension.	Reduc.	Declination.	Reduc.	Authority.
	h m s	s	° ′ ″	″	
a	0 14 38·573	+0·218	+32 15 43·87	+5·43	Micrometer comparison with Bessel 0^h 348. *a* is Arg. 32° 45.
b	0 29 54·047	0·271	32 2 27·16	5·20	Bessel 0^h 725.
c	0 33 13·856	0·284	31 59 11·95	5·21	„ 822.
d	0 59 45·265	0·378	31 33 22·10	4·78	„ 1464.
e	1 1 32·073	0·386	31 23 18·48	4·75	„ 1505.
f	1 6 24·296	0·401	31 27 15·46	4·61	Arg. 31° 197 meridian observation.
g	1 8 12·306	0·407	31 24 3·05	4·60	Bessel 1^h 109.
h	1 57 13·867	0·569	29 20 30·13	3·07	Cambridge Zones, 1879, Dec. 22.
i	2 0 9·2	0·581	29 19 43	+3·04	Arg. 29° 359.
j	3 27 29·5	0·746	22 7 54	−1·76	„ 22° 509.
k	3 30 32·978	0·757	21 57 53·20	−1·90	Bessel 3^h 620, 621.
l	3 31 7·060	0·743	21 19 23·76	−2·13	„ 631.
m	3 32 23·463	0·763	21 27 40·18	−2·13	„ 655.
n	3 37 56·876	0·740	20 22 44·20	−2·67	„ 809.
o	3 40 43·8	0·749	20 15 57	−2·77	
p	3 40 39·657	0·749	20 13 2·26	−2·78	Arg. 20° 633, meridian observation.
q	4 3 25·2	0·765	18 8 47	−4·22	Arg. 18° 493.
r	4 3 55·909	0·765	18 7 0·90	−4·22	Bessel 4^h 10, 11.

The above observations appear to show that the difference of R.A. of stars *d* and *e*, as deduced from Bessel, is 1^s in error.

The following parabolic elements have been calculated by Mr. Graham from the observations of March 3, 9, and 15 :—

T = 1883, Feb. 18·952355, G.M.T.

$$\left.\begin{aligned} \pi &= 29^\circ\ 2'\ 45''\!\cdot32 \\ \Omega &= 278\ \ 8\ 15\cdot57 \end{aligned}\right\}\text{Mean Equinox, 1883·0.}$$

$$i = 78\ \ 3\ 26\cdot33$$

log q = 9·8808596. Motion direct.

The middle place is represented thus :—

Obs. − Calc. $\Delta L \cos b = -0''\!\cdot80.$ $\Delta b = +1''\!\cdot10$;

where L and b indicate the geocentric longitude and latitude.

Observations of Comet a, 1883, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, by taking transits over two cross wires at right angles to each other, and inclined 45° to the parallel of declination.

Green. Mean Solar Time.	Obs.	$\delta - *$ R.A.	$\delta - *$ N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Star.
d h m		m s	′ ″		h m s	° ′ ″	
Mar. 9 7 55	T.	+2 11·33	+ 5 28·5	3			*a*
		+0 23·50	+ 2 18·7	3	1 8 36·03	58 38 8·3	*b*
8 45		−2 1·67	−14 2·2	3	1 8 53·60	58 38 14·0	*c*
9 0		+2 35·83	+ 6 4·8	3			*a*
		+0 47·33	+ 2 46·5	3	1 8 59·86	58 38 36·1	*b*
9 8		−1 52·00	−13 40·8	1	1 9 3·27	58 38 35·4	*c*

Mean Places of the Comparison Stars.

Star.	Star's Name.	R.A. 1883·0.	N.P.D. 1883·0.	Authority.
		h m s	° ′ ″	
a	Anonymous			
b	W. B. (2) I.−109	1 8 12·12	58 35 54·2	W. B. (2)
c	W. B. (2) I.−175–6	1 10 54·85	58 52 20·7	W. B. (2)

Note.—Comet faint and diffused.

The observations are not corrected for refraction or parallax. The comet was also observed on March 12 and 27, but the comparison stars cannot be identified.

Royal Observatory, Greenwich:
1883, *April* 13.

Spectroscopic Observations of Comet a, 1883 (*Brooks-Swift*). By Dr. N. de Konkoly.

The observations were made with the large Refractor (10-inch aperture), by Merz, on March 3, at 8^h mean time, at an altitude of 17°.

The spectroscope used was similar to that I constructed for the Brussels Observatory, with a colorimeter, made for me kindly by my friend E. de Gothard, owner of a beautiful Observatory at Herény, near Steinamanger (Hungary), with an excellent direct vision prism, by Dr. Hugo Schröder.

I saw in the spectrum only three bright bands, and with a widely-opened slit a very faint continuous spectrum, of which

I estimated the ends to be respectively 565·0 and 470·0 mm. wave-length.

I estimated the intensity of the bands at 0·6, 1·0, and 0·3. The faintest was near the violet end of the spectrum. The positions of the bands were

I.	559·9 mm. (of wave length).	
II.	515·6 „	„
III.	470·2 „	„

The lines correspond very well with the bands in the hydrocarbon spectrum.

The position of the bands given is that of their maximum intensity.

OGyalla Observatory:
1883, *March* 12.

Note on the Eclipse of Jupiter's 4th Satellite on April 4. By Capt. W. Noble.

The satellite did not even begin to fade out until some minutes after the predicted time, and did so very gradually indeed, flashing up at intervals in a way which I could hardly persuade myself was wholly referable to atmospheric undulation. I did not finally lose sight of it until $9^h\ 58^m\ 18^s$ Local Mean Time $=9^h\ 58^m\ 0^s$ G.M.T. (the longitude of my Observatory being 17·8 seconds east of Greenwich). Its disappearance was announced in the *Nautical Almanac* as occurring at $9^h\ 33^m\ 54^s$ G.M.T.; a prediction thus shown to be $24^m\ 6^s$ wrong. Of course a larger telescope than mine would have held the satellite still longer in view. I would venture to suggest that the "explanation" on pp. 501 and 502 of the *Nautical Almanac* should be supplemented by a caution as to the utter untrustworthiness of such predictions as the one on which I am commenting. I know how imperfect Damoiseau's Tables are. All I contend for is that the ephemerides calculated from them should not be given to the public without a single word of warning that they are not to be depended upon within four-and-twenty minutes. The instrument employed was my 4·2-in. Ross Equatorial, with a power of 154.

Forest Lodge, Maresfield, Uckfield:
1883, *April* 12.

[NOTE.—It was explained to the meeting by Mr. Marth, that at the beginning or end of a series of Eclipses of the Fourth Satellite the times of duration were very variable, and that the difference of 24^m did not imply any great error in the Tables, because the slightest difference in latitude made an enormous difference in the length of the chord within the shadow-cone described by the satellite.—ED.]

Observations made at the U.S. Naval Observatory, Washington. By Professor Asaph Hall.

(*Communicated by Vice-Admiral Rowan, Supt.*)

Conjunctions of the Satellites of Saturn.

Satellite.	Date.		Wash. M.T.	Position.	Wt.	Obs.
Mimas ...	1882, Oct.	5	13 11·4	S. foll.	3	H.
	Nov.	8	8 44·2	S.	2	F.
Enceladus ...	Oct.	5	13 6·4	S.	3	H.
		14	10 39·8	N.	1	H.
	Nov.	22	10 36·8	S.	3	F.
Tethys ...	Oct.	18	12 28·2	S.	3	H.
		20	9 41·6	N.	2	H.
	Nov.	21	10 40·8	S.	2	F.
		22	10 9·3	N.	3	F.
		23	9 54·8	S.	3	F.
		24	9 23·8	N.	3	F.
	Dec.	26	9 28·2	N.	2	H.
		28	6 41·8	N.	3	H.
	1883, Jan.	12	9 11·0	N.	3	H.
Dione ...	1882, Dec.	16	8 37·8	N.	2	F.
	1883, Jan.	11	8 36·4	S.	2	H
		22	7 20·4	S.	2	H.
Rhea ...	1882, Nov.	21	10 41·3	S.	2	F.
	1883, Jan.	12	9 25·5	N.	3	H.

The Companion of Sirius.

Date.		Sid. Time.	p.	s.	Wt.	Obs.
		h	°	"		
1883, Feb.	23	6·5	44·0	10·02	2	F.
	27	6·8	40·6	10·01	3	F.
	28	7·1	40·9	9·39	3	F.
Mar.	1	8·0	41·8	9·84	3	F.
	7	6·6	40·4	9·53	3	F.
	8	6·6	42·0	9·75	2	F.
	9	7·2	40·3	9·74	2	F.
	14	6·2	39·8	9·39	2	H.
	16	6·2	38·7	9·12	3	H.
	17	6·3	38·3	9·32	2	H.
	18	6·2	39·5	9·19	3	H.
	20	6·5	39·4	9·31	2	H.
	21	6·6	38·9	9·23	2	H.

Mean Results.

	p.	*s.*	
	°	″	
1883·170	41·43	9·754	E. Frisby.
1883·211	39·10	9·260	A. Hall.

Remarks.—The observed conjunctions of the satellites of *Saturn* are with the minor axis of the ring. The wire of the micrometer was set parallel to this axis by means of the angle given in the *American Ephemeris*, p. 479. The conjunction of *Mimas* on October 5 was with the following end of the principal division of the ring.

Note on the Great Comet (b) 1882.

An examination of the nucleus of this comet in the latter part of February 1883, showed two bright points of condensation, with two fainter points, one on each side of the bright ones. These four points were in a right line, and the general appearance was nearly like that given by the drawing of Mr. Prince, *Monthly Notices*, January 1883, p. 85. The following of the two bright points seemed to be the brighter, and calling this point *a*, the other bright point *b*, the preceding faint point *c*, and the following faint point *x*, the following measures were made, the origin being at *a*; *c* and *x* were very faint:—

1883.	Sid. T.	*p.*	*a* to *b*	*b* to *c*	*a* to *x*	Obs.
	h	°	″	″		
Feb. 26	6·4	257·2	34·50	47·14	—	H.
27	6·0	258·8	34·58	48·99	22·27	H.

On the Visibility of the Dark Side of Venus. By Prof. C. V. Zenger.

It is known that the first observation of the Moon's ashy light was made by Michel Maestlin in 1520, but the first observation has been also ascribed to Leonardo da Vinci, who died in that year.

A similar appearance was detected by Riccioli on January 9, 1643, on the planet *Venus* with the then discovered Galilean tube. He says: "Erat planeta Solem versus rubicunda in medio flavescens et in parte a Sole aversa cæruleo-viridis, sed illa varietas a vitro tubi probabiliter fuit." The following passage seems to indicate a very fine state of the weather: "Semi-annulus lucidus, quo a tergo coronabatur, erat forte a *Jove* et *Saturno* illam illustrantibus, utpote orientalioribus" (*Almagestum novum*). It is obvious that the reddish hue may have been partly due to the chromatic aberration of the tube, but the

greenish-blue tint of the dark side was later observed by Harding and Engelmann. Hahne saw it tinted greyish-brown, and Harding also greyish-red.

I could never see the whole dark side myself, and was much inclined to regard these observations as an involuntary illusion, imagination inducing us to complete the partly visible disk, whose circumference is obviously indicated by the part visible on the crescent. Yet there are some observations opposed to this view, by Kirch, on June 7, 1721, and March 8, 1726, when he observed that the dark side seemed a circle of less diameter than that of the crescent. He mentions that he once more saw the entire dark side of *Venus* on October 20, 1759, at noon, although the southern declination of 21° 50′ greatly interfered with a good definition.

Harding made the most trustworthy and accurate observations of any observer, using a large reflector of 10 feet focal length, and a power of 84 diameters. He also saw *Venus* beautifully on January 28, 1806, with the whole aperture of the reflector, and the cusp projecting over the dark side. Another time, February 20, 1806, at 6^h 12^m, he saw again the entire disk of *Venus*, of reddish-grey hue. Schröter saw, on February 14, 7^h, *Venus* for the first time entire, with the reflector of 20 inches aperture, and 27 feet focal length, in a very feeble light, the hue of which he does not describe.

Gruithuisen, on June 7, 16^h (21 days after conjunction), likewise saw the phenomenon well, though at low altitude.

Finally, Engelmann, on April 20, 1865, Banks, Green, Noble, and Arcimis, 1877, Noble, Mills and Webb, 1878, have seen the phenomenon; but Lassell could not see a trace of the dark side, though he observed with a powerful instrument. This may be perhaps due to the very far advanced diminution of the crescent, which he describes as a hair of light rather than a crescent. The feeble light of the dark side must then vanish, *Venus* being so near to the blazing sunlight; and indeed he says that some days afterwards solar light still invaded the tube and seriously disturbed accurate vision. Though the observers agree as to a greyish colour of the dark side, yet they differ considerably as to the additional tint, calling it reddish, brownish, greenish, ashy, &c. It seemed to me desirable to observe *Venus* after conjunction for the purpose of deciding upon the visibility of the dark side, and the ring, observed solely by Riccioli.

I prepared in the first instance to correct the 4-inch Equatorial I intended to use for the observation as far as possible for all chromatic aberration. A fine specimen of a Barlow lens by Browning was placed in the tube; the objective being slightly under corrected, it was possible to get rid of all traces of colour by placing the Barlow lens in the right position to the objective lens. Trying it on the planet itself till all traces of colour disappeared seemed to me the safest and most expeditious means. It was only in entire darkness that a trace of reddish colour

could be detected on the outer edge of the crescent. Aplanatism was nearly perfect.

Prepared in this manner I waited in the discomforting season of 1882 in vain for a suitable opportunity. Finally, in January 1883, a couple of most splendid mornings favoured us in Prague, accompanied by heavy frost, and no trace of cloud visible all over the horizon. It was possible to set to work at once, and it was first possible on January 8, and then on January 9, between 18^h and 20^h, to see *Venus* beautifully with powers of 60 and 120 diameters, projected on a cloudless dark blue sky.

I did not expect to see such a ravishing spectacle as was disclosed at once to my sight on the 8th inst., $18^h\ 45^m$; *Venus* not only was visible as a whole disk, but there was an amount of detail in the aspect that I believe to be sufficient proof of the reality of the phenomenon. The crescent overlapped nearly 8″ (at least) the adjacent border of the unilluminated part of the disk, the terminator was all along its length serrated, and the reddish-yellow light of dawn invaded the dark disk for at least $\frac{1}{8}$th of the whole diameter, shading down and fading away on the border of the dark part. This was splendidly visible even to the unaccustomed eye of entirely uninstructed persons, to whom I did not mention the appearance of the planet, but who had seen the Moon as a crescent. They at once recognised the whole disk, well defined and projected on the dark blue sky.

But the most important feature of the observation was the ring, that I could detect all round the disk (dark part and crescent), of brownish-red colour, more pronounced on the illuminated side than on the dark part of the limb, but of a peculiar coppery hue, the close resemblance of which to the coppery hue the Moon's disk assumes when totally eclipsed was very striking.

As it is certain this hue is due to the absorption of the more refractive part of terrestrial light in the atmosphere of the Earth, it seems to me very probable that the reddish-brown ring of light round *Venus* is due to refracted light in the atmosphere, and to the reflected light from the clouds in the planet's atmosphere. Now, supposing *Venus's* atmosphere to be similar to our own, a similar hue by selective absorption must be produced, and the cause of resemblance of the colour of the eclipsed Moon and of the ring round *Venus* is then obvious.

At $18^h\ 56^m$, January 9, I could discern on the southern horn a most striking feature, very near to the end of the southern cusp, which was more sharply edged than the northern one. It was not only indented as the other parts of the terminator, but there was clearly seen an object of perhaps 1″ of diameter standing out boldly in the midst of a more or less greyish-tinted elliptical zone, forming a deep indentation of the end of the terminator. The shading round it was very well visible, and it seemed to me a high mountain of oblong form, piercing with its refulgent light through the surrounding valleys still immersed in half shadow or in full shadow. This is the second time that

I have observed such an isolated brilliant point of appreciable diameter on the southern cusp of *Venus* (*Monthly Notices*, 1877, p. 460).

The dark part of *Venus* seemed to me not bluish-grey, nor greenish-grey; but from the terminator, where the dawning of sunlight produced a pronounced reddish-yellow zone, it faded away to a decidedly reddish-grey tint, bordered by the more luminous reddish-brown of the extremely narrow ring of perhaps atmospheric origin.

We can scarcely imagine a more probable supposition of its nature than a similarity of absorbing power of the terrestrial atmosphere and of *Venus's* atmosphere producing the same coppery hue as is visible on the eclipsed Moon's surface, illuminated by the reflected rays of sunlight from the Earth's surface, and deprived by selective absorption of the more refrangible rays.

Prague,
1883, *Jan.* 10.

Addition.

It happened that on the 11th and 12th of January, the Moon was a small crescent, and the atmosphere of extraordinary steadiness and clearness, showing the Moon's ashy light with most remarkable clearness, the mountains being visible as I had never seen them before in the dark side.

It was after a most trying period of wet and cloudy weather that the sky began to clear up from the 7th, the 8th being again cloudy, but from the 9th to the 13th there was a singular clearness all over the heavens, there being a deep blue from morning to evening. It was this clearness that obviously increased the visibility of the dark side of *Venus* as well as of the Moon. But it shows also clearly to me the parallelism of the phenomena of visibility of the dark sides of *Venus* and of the Moon. On the 12th, and after, the dark side of the Moon was no longer visible to the naked eye, and it was the same with the crescent of *Venus*. It is only possible to see its dark side to advantage, if:—

1. The atmospheric conditions are exceptionally fine;
2. If a certain part of the disk is only illuminated, and *Venus* is at her greatest luminosity, or near to it, as has just been the case.

There is a certain advantage if the luminous part is not too great, and if it is in its greatest luminosity; the feeble light of the dark side is then likewise at its utmost visibility.

Venus' dark side is therefore visible not by fluorescence of the sea, nor by auroral light, but simply by the same causes as those that make the Moon's dark side visible.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. XLIII. May 11, 1883. No. 7.

E. J. Stone, M.A., F.R.S., President, in the Chair.

James Lawson, Houghton House, Ealing;
Emanuel Ristori, 13 Pemberton Crescent, Bayswater; and
Walter George Woollcombe, B.A., The College, Brighton;

were balloted for and duly elected Fellows of the Society.

An Explanation of the Principal Cause of the large Errors at present existing between the Positions of the Moon deduced from Hansen's Tables and from Observation; and the Cause of an Apparent Increase in the Secular Acceleration in the Moon's Mean Motion required by the Tables, or of an Apparent Change in the Time of the Earth's Rotation. By E. J. Stone, M.A., F.R.S.

The errors in the Lunar Theory have been traced to the effects of changes in the *unit of time*, or in the point of reference from which our theoretical longitudes are measured, which have, apparently unconsciously, been introduced from time to time into astronomy with changes in the adopted data.

The argument is clearly seen by a consideration of the different expressions for the longitudes of what may be called the mean Sun which have been adopted for the determination of the sidereal times at mean noon.

If B, H, and V denote the longitudes of the mean Sun, according to Bessel, Hansen, and Le Verrier, we have for 1850 Jan. 1, Paris mean noon $+t$.

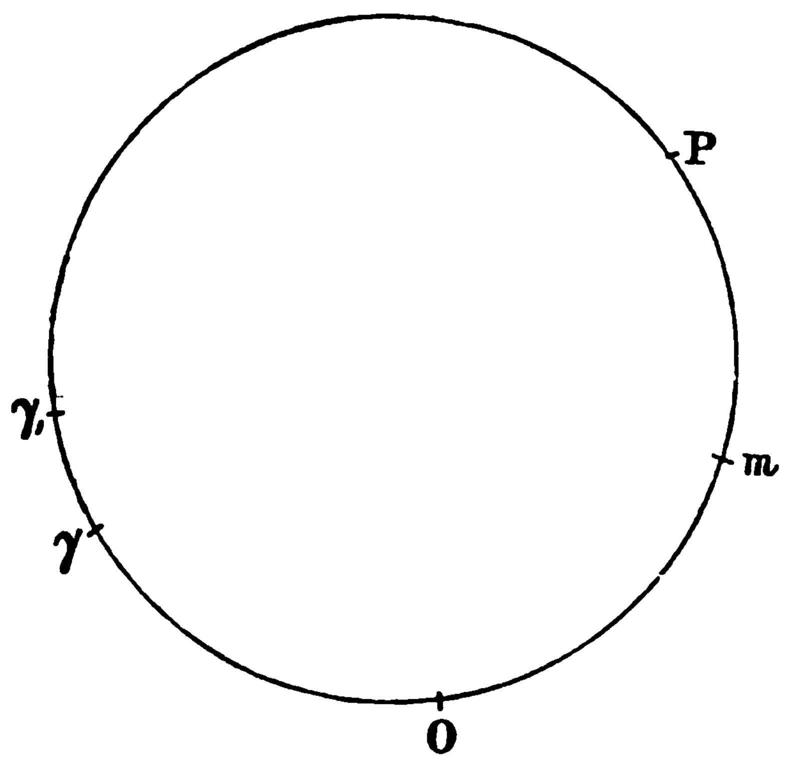
$$B = 280^\circ\ 46'\ 36''\cdot12 + 1296027''\cdot618184 \,.\, t + 0''\cdot0001221805 \,.\, t^2$$

$$H = 280\ \ 46\ \ 43\cdot20 + 1296027\cdot674055 \,.\, t + 0\cdot0001106850 \,.\, t^2$$

$$V = 280\ \ 46\ \ 43\cdot51 + 1296027\cdot678400 \,.\, t + 0\cdot0001107300 \,.\, t^2$$

G G

To get rid of the effects of the diurnal rotation I have referred everything to the meridian of some Observatory, as Paris, and discussed the changes of sidereal times at *mean* Paris noons; but as there is apparently some difficulty in following this reasoning, which is based upon the principle of continuity, I give a direct proof of the legitimacy of the method adopted in throwing the changes in the law fixing the position of the point from which our theoretical R.As. are measured, relatively to the Paris meridian at mean noon, on the time in the case of the mean Sun, from whose motion our ideas of mean solar time are derived, and on the determinations of the *mean* motions for the Moon and the planets.



If we assume the time of the Earth's rotation on its axis to be constant—an assumption to be tested by the results—we can always determine the position, relatively to our meridian, of a fixed point on the equator at any definite time. Let this point be O. This is a simplification merely to get rid of the complication of ideas arising from the diurnal motion.

Let m be the mean Sun by whose motion our time is to be measured, and at time t, expressed in any definite unit, let its position be at m, so that

$$\mathrm{O}m = nt$$

(n is a *definite* numerical quantity, since the rotation of the Earth on its axis is supposed to be assigned); and at the same time let P be a planet, and

$$\mathrm{OP} = \mathrm{A} + n't.$$

For practical convenience we measure our angles from γ, where

$$\mathrm{O}\gamma = \mathrm{C} + at + st^2,$$

C, a, and s being assigned constants.

$$\therefore\ \gamma m = C + (a+n)t + st^2$$
$$\gamma P = C + A + (a+n')t + st^2.$$

But suppose, instead of referring our angles to γ, we refer them, in our theoretical investigations, to $\gamma_{,}$, such that

$$O\gamma_{,} = C + \delta C + (a + \delta a)t + (s + \delta s)t^2\,;$$

then

$$(1)\quad \gamma_{,}m = C + \delta C + (a + n + \delta a)t + (s + \delta s)t^2,$$

t having the *same* value as before.

$$(2)\quad \gamma_{,}P = C + \delta C + A + (a + \delta a + n')t + (s + \delta s)t^2.$$

Now, if we know of the changes δC, δa, δs, and allow for them, we shall correctly determine the relative motion of P measured from $\gamma_{,}$; but if we do not know of these changes, and do not allow for them, how shall we force an agreement between observation and theory? Clearly we shall have to throw the error on the time measured from (1), and on the mean motions of the planets in (2), and we shall thus partially force an agreement, but not a complete one, between observations referred to γ and theory referred to $\gamma_{,}$.

First, let t be the true time deduced either from γm or $\gamma_{,}m$; and let $(t+\delta t)$ be the observed time deduced from (1) when δC, δa, and δs are neglected, or when $\gamma_{,}m$ is forced to agree with observations referred to γ; and let B be the epoch, x the mean motion, and yt^2 the empirical secular correction required to make $\gamma_{,}P$, deduced with the time $(t+\delta t)$, agree with γP; we then have

$$\gamma_{,}P = B + x(t+\delta t) + (s + \delta s + y)t^2\,;$$
$$= C + A + (a+n')t + st^2.$$

But from (1) we have

$$O = \delta C + (a+n)\delta t + \delta a\,.\,t + \delta s\,.\,t^2$$
$$\delta t = \frac{-(\delta C + \delta a\,.\,t + \delta s\,.\,t^2)}{a+n},$$

$$\gamma_{,}P = B - \frac{x\,.\,\delta C}{a+n} + x\left(1 - \frac{\delta a}{a+n}\right)t + \left(s + y + \delta s - \frac{\delta s\,.\,x}{a+n}\right)t^2$$
$$= C + A + (a+n')\,.\,t + st^2$$
$$\therefore\ B - \frac{x\,.\,\delta C}{a+n} = C + A$$
$$x\left(1 - \frac{\delta a}{a+n}\right) = (a+n')$$

$$s + y + \delta s - \frac{\delta s \,.\, x}{a + n} = s$$

$$\therefore \; x = (a + n')\left(1 + \frac{\delta a}{a + n}\right)$$

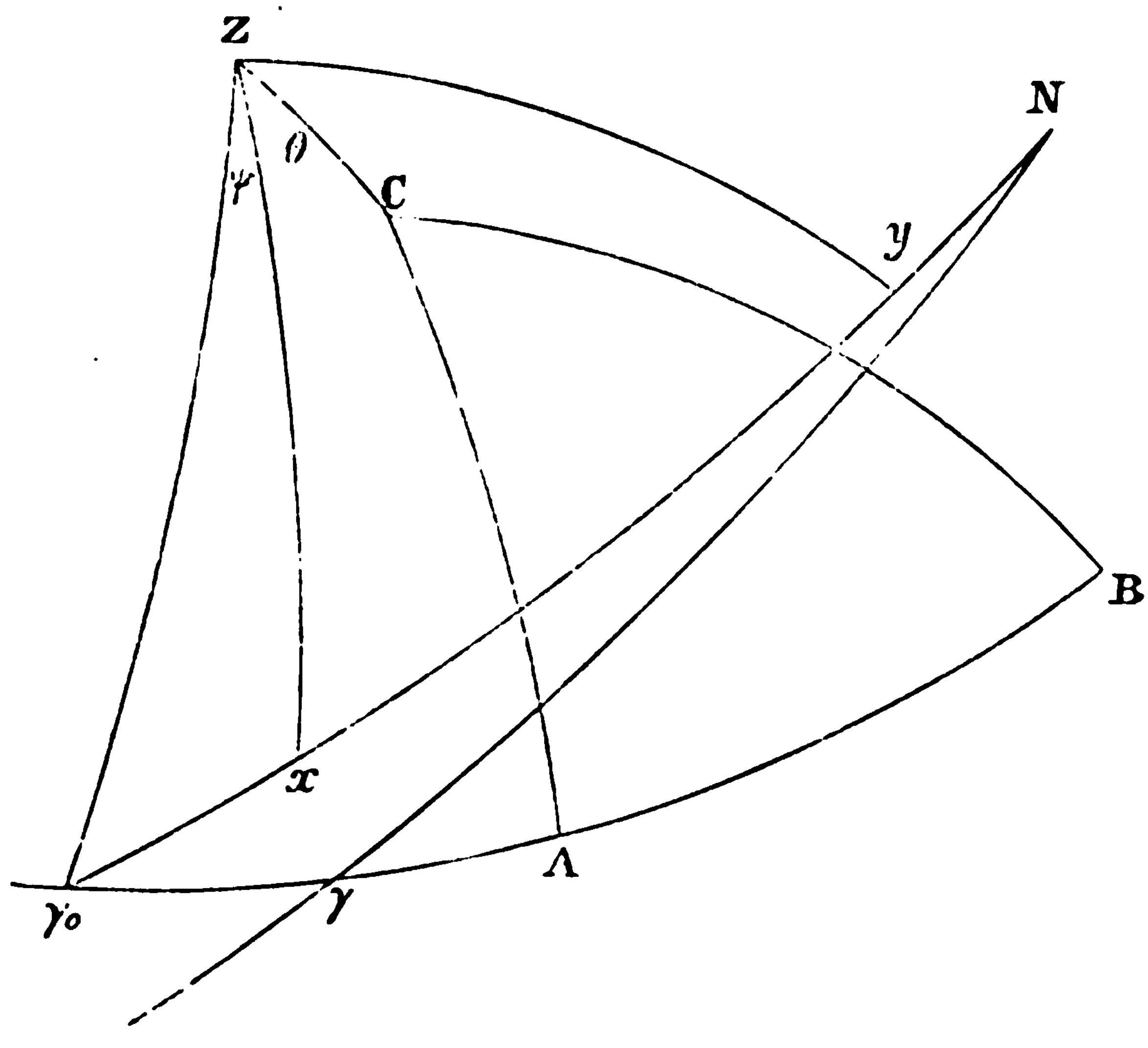
$$B = C + A + \delta C\left(\frac{a + n'}{a + n}\right)$$

$$y + \delta s = \delta s\left(\frac{a + n}{a + n}\right)$$

The correction required to γ P deduced directly from the erroneous time to make it agree with the observations referred to γ is therefore

$$-(\delta C + \delta a \,.\, t + \delta s \,.\, t^2)\left(\frac{a + n'}{a + n}\right),$$

which is the condition upon which the investigation in my paper is based as deduced directly from the consideration of the differences in the units of time necessary to secure continuity in the adopted expressions for sidereal time at mean noon. The possibility of such errors arises from the indirect way in which our theories are compared with observation. Numerical values of the constants which fix the relative changes in the planes and points of reference and the mean motion of Sun have to be adopted and carried into the theories; but the observed R.As. are deduced from the times of transit by clocks whose errors are determined by the differences between the times of transit by the clock and R.As. measured from the point of intersection of the ecliptic and equator, which point must, for accurate work, be the same as that adopted in the theoretical expressions. I have shown, however, by the discordant values of B, H and V, that no definite point, much less the true point, has been practically adopted in our theories.



The breaks of continuity in our measures which have necessarily taken place with the adoption of different units through the introduction of small changes in the Sun's mean notion, and in the secular terms which express the relative motions of the planes of reference, are clearly shown as follows :—

Let x, y, Z be the projections of three rectangular axes fixed in space, xy being the plane of the ecliptic and x the point of intersection of the ecliptic and equator at the instant from which our time is measured ; and at the time t let γ_0AB be the plane of the equator, γN the plane of the ecliptic, C the projection of the polar axis of the Earth, and CA the meridian of the Paris Obsertory.

Let

$$\text{ZC} = \theta; \qquad \gamma_0 \text{Z}x = \psi; \qquad \gamma_0 \text{A} = \phi;$$

n = angular velocity of the Earth on its axis.

Then

$$n = \frac{d\phi}{dt} - \frac{d\psi}{dt} . \cos\theta.$$

This equation is exact.

And

$$\phi = \text{C} + nt + \int \frac{d\psi}{dt} . \cos\theta . dt,$$

where C is some constant to be determined from observation. From the theory of the motion of the Earth about its centre of gravity, we have, to the second power of t,

$$(1) \quad \psi = at + bt^2 + \Psi,$$
$$(2) \quad \theta = \omega_0 + ft^2 + \Omega;$$

where a, b, ω_0, f are constants, Ψ and Ω periodic functions.

$$\therefore \quad \int \frac{d\psi}{dt} . \cos\theta . dt = at \cos\omega_0 + bt^2 \cos\omega_0 + \Psi . \cos\omega_0,$$

and

$$\phi = \text{C} + (n + a\cos\omega_0) . t + bt^2 \cos\omega_0 + \Psi . \cos\omega_0.$$

But from the relative motion of the Sun around the Earth, we have

$$(3) \quad x\text{N} = \alpha - \beta t; \qquad (4) \quad \gamma_0 \text{N} \gamma = \gamma t + \epsilon t^2,$$

where α, β, γ, and ϵ are constants.

From (1), (2), (3), and (4) we obtain

$$\gamma_0 \gamma \doteq ut + u't^2; \text{ where } u \text{ and } u' \text{ are constants.}$$

But

$$\gamma A = \phi - \gamma_C \gamma = s, \text{ suppose};$$

$$s = C + (n + a \cos \omega_0 - u)t + (b \cos \omega_0 - u')t^2 + \Psi \cos \omega_0.$$

This equation fixes the law of variation of γ the point from which the R.As. are measured, relatively to A, a fixed point on the Earth's surface; and nothing but confusion can result from any alteration in this expression unless the changes in the constants by which it is produced are consistently carried through all our work.

Now suppose the mean longitude of the Sun

$$= L_0 + Nt + \lambda t^2.$$

Let

$$n + a \cos \omega_0 - u - N = 365\cdot25 \times 2\pi;$$

this fixes the unit of time where

n = angular velocity of Earth on its axis,
a = luni-solar precession,
ω_0 = obliquity at 1850, Jan. 1,
u = intercept on Equator between ecliptic-planes,
n' = Sun's sidereal mean motion in longitude,
p = general precession.
$N = n' + p$.

All these quantities, when expressed numerically, have to be referred to a Julian year of 365·25 mean solar days. But since the rotation of the Earth on its axis, and the Sun's mean motion in longitude are physical facts, we must have

$$\frac{n}{n'} = C,$$

where C is a constant to be determined from observation; and this relationship must hold good *whatever unit of time be adopted*, and be carried into the equation of condition which fixes the unit of time from the relative motions of the Earth on its axis, and the Sun's mean motion in R.A.

Similarly we may write

$$a \cos \omega_0 - u - p = An';$$

where A is some constant.

Our equation of condition which defines the unit of time then becomes

$$n'(C - 1 + A) = 365\cdot25 \times 2\pi. \qquad (2)$$

This equation shows at once that we cannot change n' without changing our unit of time. We can of course write

$$(n' + \delta n')(C - 1 + A) = 365\cdot25 \times 2\pi, \qquad (3)$$

and still *call* the new unit of time a *Julian year*, but in this case the length of a Julian year in (3) is not the same as in (2); and if t_1 and t_2 are the lengths of the two so-called Julian years, we must have

$$t_1 n' = t_2(n + \delta n'); \tag{4}$$

therefore

$$t_1 = t_2\left(1 + \frac{\delta n'}{n'}\right). \tag{5}$$

From which it directly follows that if a period be expressed by t Julian years under system (2), it will exceed the period expressed by t Julian years under system (3) by

$$\frac{\delta n'}{n'} \cdot t. \tag{6}$$

I now proceed to show how it has been frequently assumed that the error due to a change $\delta n'$ is only

$$= \frac{\delta n'}{n} \cdot t, \text{ instead of } \frac{\delta n'}{n'} \cdot t.$$

Let n and $n + \delta n$ be the angular velocities of the Earth on its axis, corresponding to the two values n' and $(n' + \delta n')$ of the Sun's mean motion. Then

$$n = 365{\cdot}25 \times 2\pi + n' + p + u - a \cos \omega_0; \tag{7}$$

but it is then usually assumed that

$$n + \delta n = 365{\cdot}25 \times 2\pi + n' + \delta n' + p + u - a \cos \omega_0, \tag{8}$$

from which of course would follow

$$\delta n = \delta n',$$

and

$$\frac{\delta n}{n} = \frac{\delta n'}{n};$$

but upon this I must remark that since t_1 and t_2 cannot *both* be put $= 1$, we must have instead of (8), the equation of condition

$$n + \delta n = 365{\cdot}25 \times 2\pi(1 + x) + n' + \delta n' + (1 + x)(p + u - a \cos \omega_0). \tag{9}$$

(The change of unit in n' is allowed for in $\delta n'$.)

$$\therefore\ \delta n = 365{\cdot}25 \times 2\pi x + \delta n' + x(p + u - a \cos \omega_0);$$

$$\therefore\ \delta n = \frac{\delta n'}{n'}(365{\cdot}25 \times 2\pi + n' + p + u - a \cos \omega_0);$$

$$= \frac{\delta n'}{n'} \cdot n;$$

$$\therefore\ \frac{\delta n}{n} = \frac{\delta n'}{n'};$$

or the change of unit of time is as

$$1 : 1 + \frac{\delta n'}{n'},$$

as before proved.

Since the epoch from which t is measured is not yet fixed, let it be so chosen that

$$C = L_0.$$

Then

$$s = L_0 + Nt + 365{\cdot}25 \times 2\pi \times t + (b \cos \omega_0 - u')t^2 + \Psi . \cos \omega_0.$$

If the epoch thus chosen be called 1850, Jan. 1, Paris mean noon, we have for the computation of the distance γ from A at the different Paris mean noons,

$$S_0 = L_0 + Nt + (b . \cos \omega_0 - u') . t^2 + \Psi . \cos \omega_0.$$

The non-periodic part of S_0 only differs from the mean longitude of the Sun by

$$\{\lambda - (b . \cos \omega_0 - u')\} . t^2.$$

If, therefore, we call

$$L = L_0 + Nt + (b . \cos \omega_0 - u') . t^2$$

the longitude of the mean Sun, the mean longitude of the Sun

$$= L + \{\lambda - (b . \cos \omega_0 - u')\} . t^2.$$

Here

$$\{\lambda - (b \cos \omega_0 - u')\} . t^2$$

is a small secular term which, with the data adopted in Le Verrier's Tables—

$$= -0{\cdot}00003113 . t^2 = -0{\cdot}3113\left(\frac{t}{100}\right)^2.$$

If it should be found absolutely necessary, in the progress of science, to introduce corrections δN and $\delta\lambda$ to N and λ in order to represent the solar observations, we must keep

$$L = L_0 + Nt + (b \cos \omega_0 - u')t^2$$

still unchanged, but put the mean longitude of the Sun

$$= L + \delta Nt + (\delta\lambda - 0{\cdot}00003113) . t^2.$$

If the constants determining the motions of the planes of reference and the mean motion of the Sun are accurately known, we shall, in this way, have for a very long period the point of *reference* γ coincident with the point of intersection of the ecliptic and equator; but even if this condition is not quite satisfied, we must not change γ by changing the law of variation of $A\gamma$ until we deliberately change our unit of time, and carry

logically through all our work the consequences of that change. If the difference $0.3113\left(\frac{t}{100}\right)^2$ between the longitude of the mean Sun and the mean longitude of the Sun be neglected (and this has usually been done), it would lead to the apparent necessity of an increase of about $4''.16$ in the secular acceleration of the Moon's mean motion. This quantity agrees very closely with the supposed discordance between theory and observation. It would appear, therefore, that the discordance between theory and observation which has recently been thrown on the Earth's rotation no longer exists to any proved sensible extent, and, so far as we know at present, the time of the Earth's rotation is constant.

[This abstract was drawn up for the Society's publications by request, after a verbal explanation of the paper, which was given at the meeting of April 13, 1883.]

On the Computation of the Eccentric Anomaly, Equation of the Centre and Radius Vector of a Planet, in Terms of the Mean Anomaly and Eccentricity. By J. Morrison, M.D., M.A., Assistant on the American *Ephemeris and Nautical Almanac*, Washington, D.C.

(*Communicated by the Foreign Secretary.*)

Several methods of computing the eccentric anomaly of a planet from the eccentricity and mean anomaly have already been given, in the *Monthly Notices* and elsewhere, by many very able mathematicians. Some of these methods involve considerable labour even after the formulæ have been deduced, while others give only rough approximations. The following method of treating the subject is due, I believe, to the late Professor Hansen, as indicated by him in the *Abhandlungen der Sächsischen Gesellschaft der Wissenschaften*, Band II. It gives the eccentric anomaly with great accuracy and facility by means of rapidly converging series, and in most cases with very little labour, especially after the coefficients of the several terms of the series have been computed for each planet. I purpose in this short paper to develop the subject more fully than is done in the work referred to, and to apply the results to the computation of the eccentric anomaly in the case of each of the primary planets, as well as of the equation of the centre and the radius vector.

Let

$$\begin{aligned} M &= \text{the Mean Anomaly,} \\ E &= \text{the Eccentric Anomaly,} \\ \nu &= \text{the True Anomaly,} \\ e &= \text{the Eccentricity,} \end{aligned}$$

and

$$\epsilon = \text{the Napierian base}\cdot$$

then we have the following well-known relations:

$$M = E - e \sin E; \tag{1}$$

$$\tan \tfrac{1}{2}\nu = \sqrt{\frac{1+e}{1-e}} \cdot \tan \tfrac{1}{2}E. \tag{2}$$

Hansen assumes

$$y = \epsilon^{E\sqrt{-1}},$$

and

$$z = \epsilon^{M\sqrt{-1}};$$

that is,

$$y = \cos E - \sqrt{-1} \sin E,$$

and

$$z = \cos M + \sqrt{-1} \sin M,$$

and represents the coefficients of the series to be developed according to the sine and cosine of multiples of E by $P_h^{(i)}$ and $Q_i^{(h)}$, thus

$$y^i = \sum_{i=-\infty}^{i=\infty} P_h^{(i)} z^h \tag{3}$$

$$z^h = \sum_{h=-\infty}^{h=\infty} Q_i^{(h)} y^i \tag{4}$$

where h and i are *integers*, and it is evident from the form of the series that we must have

$$P_h^{(i)} = P_{-h}^{-(i)}$$

and

$$Q_i^{(h)} = Q_{-i}^{-(h)},$$

except in the case of $h = 0$.

Relation between $P_h^{(i)}$ *and* $Q_i^{(h)}$.

Put

$$h = i + \mu \text{ in } (3),$$

and we shall have

$$y^i = \sum_{i=-\infty}^{i=\infty} P_{i+\mu}^{(i)} z^{i+\mu}.$$

Multiply by $z^{-\mu} dM$ and integrate between the limits π and $-\pi$, thus

$$P_{i+\mu}^{(i)} = \frac{1}{2\pi} \int_{-\pi}^{\pi} y^i z^{-\mu-i} dM$$

$$= \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^i z^{-\mu-i-1} dz \tag{5}$$

since

$$dM = -\frac{dz}{z\sqrt{-1}}.$$

Again, in (4) put $i=h+\nu$, multiply by $y^{-\nu}dE$, and integrate between the limits π and $-\pi$, thus

$$Q_{h+\nu}^{(h)} = \frac{1}{2\pi}\int_{-\pi}^{\pi} y^{-\nu-h} z^h dE$$

$$= \frac{1}{2\pi\sqrt{-1}}\int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{-\nu-h-1} z^h dy \qquad (6)$$

since

$$dE = \frac{dy}{y\sqrt{-1}}.$$

Let

$$i+\mu=h, \text{ and } h+\nu=i;$$

that is

$$\mu+\nu=0.$$

Then (5) and (6) become

$$P_h^{(i)} = \frac{1}{2\pi\sqrt{-1}}\int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^i z^{-h-1} dz, \qquad (7)$$

$$Q_i^{(h)} = \frac{1}{2\pi\sqrt{-1}}\int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{-i-1} z^h dy. \qquad (8)$$

Integrating (7) by parts, we have,

$$P_h^{(i)} = \frac{1}{2\pi\sqrt{-1}}\cdot\frac{i}{h}\int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{i-1} z^{-h} dy, \qquad (9)$$

Comparing (8) and (9), we have

$$P_h^{(i)} = \frac{i}{h}\,Q_{-i}^{-(h)} = \frac{i}{h}\,Q_i^{(h)},$$

the required relation.

Eliminating E and M from the equations

$$y=\epsilon^{E\sqrt{-1}},\quad z=\epsilon^{M\sqrt{-1}}, \text{ and } M=E-e\sin E,$$

we get

$$z = y\,\epsilon^{-\frac{1}{2}e(y-y^{-1})},$$

which, substituted in (8), gives

$$Q_i^{(h)} = \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{h-i-1} \epsilon^{-\frac{1}{2}eh\,(y-y^{-1})} dy \qquad (10)$$

Put

$$\lambda = -\tfrac{1}{2}eh,$$

and develop

$$\epsilon^{\lambda\,(y-y^{-1})},$$

by the exponential theorem, thus

$$\epsilon^{\lambda\,(y-y^{-1})} = 1 + \lambda\,(y-y^{-1}) + \frac{\lambda^2}{1\,.\,2}\,(y-y^{-1})^2 + \frac{\lambda^3}{1\,.\,2\,.\,3}\,(y-\ \ ^{-1})^3 + \text{etc.}$$

$$= \left(1 - \frac{\lambda^2}{1^2} + \frac{\lambda^4}{2^2} - \frac{\lambda^6}{6^2} + \frac{\lambda^8}{24^2} - \frac{\lambda^{10}}{120^2} + \,.\,.\,.\,.\,.\,.\right) y^0$$

$$+ \left(\lambda - \frac{\lambda^3}{1\,.\,2} + \frac{\lambda^5}{2\underline{|3}} - \frac{\lambda^7}{6\underline{|4}} + \frac{\lambda^9}{4\underline{|6}} - \,.\,.\,.\,.\,.\,.\,.\,.\right) y$$

$$+ \left(-\lambda + \frac{\lambda^3}{1\,.\,2} - \frac{\lambda^5}{2\underline{|3}} + \frac{\lambda^7}{6\underline{|4}} - \frac{\lambda^9}{4\underline{|6}} - \,.\,.\,.\,.\,.\,.\,.\,.\right) y^{-1}$$

$$+ \left(\frac{\lambda^2}{\underline{|2}} - \frac{\lambda^4}{\underline{|3}} + \frac{\lambda^6}{2\underline{|4}} - \frac{\lambda^8}{\underline{|6}} + \frac{\lambda^{10}}{24\underline{|6}} - \,.\,.\,.\,.\,.\,.\,.\,.\right) y^2$$

$$+ \left(\frac{\lambda^2}{\underline{|2}} - \frac{\lambda^4}{\underline{|3}} + \frac{\lambda^6}{2\underline{|4}} - \frac{\lambda^8}{\underline{|6}} + \frac{\lambda^{10}}{24\underline{|6}} - \,.\,.\,.\,.\,.\,.\,.\,.\right) y^{-2}$$

$$+ \left(\frac{\lambda^3}{\underline{|3}} - \frac{\lambda^5}{\underline{|4}} + \frac{\lambda^7}{2\underline{|5}} - \frac{\lambda^9}{6\underline{|6}} + \frac{\lambda^{11}}{24\underline{|7}} - \,.\,.\,.\,.\,.\,.\,.\right) y^3$$

$$+ \left(-\frac{\lambda^3}{\underline{|3}} + \frac{\lambda^5}{\underline{|4}} - \frac{\lambda^7}{2\underline{|5}} + \frac{\lambda^9}{6\underline{|6}} - \frac{\lambda^{11}}{24\underline{|7}} + \,.\,.\,.\,.\,.\,.\right) y^{-3}$$

$$+ \,.$$

$$+ \frac{\lambda^m}{\underline{|m}}\left(1 - \frac{\lambda^2}{1\,.\,m+1} + \frac{\lambda^4}{1\,.\,2\,.\,m+1\,.\,m+2}\right.$$

$$\left. - \frac{\lambda^6}{1\,.\,2\,.\,3\,.\,m+1\,.\,m+2\,.\,m+3} + \,.\,.\,.\,.\right) y^m$$

where m must be considered a positive integer.

Let us now represent the coefficient of y^m by $J^{(m)}_\lambda$ (Hansen's notation for the Besselian Function); then the above series may be written thus :

$$\epsilon^{\lambda\,(y-y^{-1})} = \sum_{m=-\infty}^{m=\infty} J^{(m)}_\lambda y^m, \qquad (11)$$

and from the form of the preceding development we notice that

$$J^{(-m)}_\lambda = (-1)^m J^{(m)}_\lambda, \quad J^{(m)}_{-\lambda} = (-1)^m J^{(m)}_\lambda, \quad J^{(-m)}_{-\lambda} = J^{(m)}_\lambda.$$

From the last two equations we have,

$$Q_i^{(h)} = \frac{1}{2\pi\sqrt{-1}} \sum_{m=-\infty}^{m=\infty} J_\lambda^{(m)} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{h-i-m-1} dy. \qquad (12)$$

Now, since

$$\int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^n dy = 0,$$

when n is an integer and

$$\int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{-1} dy = 2\pi\sqrt{-1},$$

we must have $h-i-m=0$, otherwise (12) would vanish; therefore we have

$$Q_i^{(h)} = \frac{1}{2\pi\sqrt{-1}} \sum_{m=-\infty}^{m=\infty} J_\lambda^{(m)} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{-1} dy$$

$$= \sum_{m=-\infty}^{m=\infty} J_\lambda^{(m)};$$

hence

$$P_h^{(i)} = \frac{i}{h} \sum_{m=-\infty}^{m=\infty} J_\lambda^{(m)}.$$

But

$$y^i = \sum_{i=-\infty}^{i=\infty} P_h^{(i)} z^h = \frac{i}{h} \sum_{h=-\infty}^{h=\infty} J_\lambda^{(h-i)} z^h;$$

and also

$$y^i = \cos iE + \sqrt{-1}\sin iE$$

$$z^h = \cos hM + \sqrt{-1}\sin hM;$$

therefore we have

$$\cos iE + \sqrt{-1}\sin iE = \frac{i}{h} \sum_{h=-\infty}^{h=\infty} J_\lambda^{(h-i)} (\cos hM + \sqrt{-1}\sin hM).$$

Equating the real and imaginary parts of this equation we have

$$\cos iE = \frac{i}{h} \sum_{h=-\infty}^{h=\infty} J_\lambda^{(h-i)} \cos hM \qquad (13)$$

$$\sin iE = \frac{i}{h} \sum_{h=-\infty}^{h=\infty} J_\lambda^{(h-i)} \sin hM \qquad (14)$$

When $h=0$, the second members of the last two equations assume the form $\frac{0}{0}$; hence it becomes necessary to evaluate them. Putting $h=0$ in (7) it becomes

$$P_0^{(i)} = \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^i z^{-1} dz.$$

Differentiating

$$z = y\epsilon^{-\frac{1}{2}e(y-y^{-1})}$$

we get

$$z^{-1} dz = y^{-1} dy - \frac{e}{2}(1 + y^{-2})\, dy,$$

which, substituted in the preceding equation, gives

$$P_0^{(i)} = \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} (y^{i-1} - \frac{e}{2} y^i - \frac{e}{2} y^{i-2}) dy$$
$$= 0,$$

for all values of i greater than 1 or less than -1. Therefore, 0, 1 and -1 are the values of i, which make the second members of (13) and (14) take the form $\frac{0}{0}$.

When $i=0$, we have

$$P_0^{(0)} = \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} (y^{-1} - \frac{e}{2} - \frac{e}{2} y^{-2}) dy$$

$$= \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} y^{-1} dy - \frac{1}{2\pi\sqrt{-1}} \cdot \frac{e}{2} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} (1 + y^{-2}) dy$$
$$= 1 - 0 = 1.$$

When $i=1$, we have

$$P_0^{(1)} = \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} (1 - \frac{e}{2} y - \frac{e}{2} y^{-1}) dy = \tfrac{1}{2}e.$$

When $i=-1$, we have

$$P_0^{(-1)} = \frac{1}{2\pi\sqrt{-1}} \int_{\epsilon^{-\pi\sqrt{-1}}}^{\epsilon^{\pi\sqrt{-1}}} (y^{-2} - \frac{e}{2} y^{-1} - \frac{e}{2} y^{-3}) dy = -\tfrac{1}{2}e.$$

For all other values of i we have

$$P_0^{(i)} = 0.$$

From (13) we find, when $i=1, 2,$ &c.

$$
\begin{aligned}
\cos E = -\frac{e}{2} &+ \left(1 - \frac{3e^2}{2^3} + \frac{5e^4}{2^6 . 3} - \frac{7e^6}{2^{10} . 3^2} + \frac{e^8}{2^{14} . 5} - \frac{11e^{10}}{2^{17} . 3^3 . 5^2} + \ldots\right)\cos M \\
&+ \left(\frac{e}{2} - \frac{e^3}{3} + \frac{e^5}{2^4} - \frac{e^7}{2^2 . 3^2 . 5} + \frac{e^9}{2^7 . 3^3} - \frac{e^{11}}{2^8 . 3^2 . 5^2 . 7} + \ldots\right)\cos 2M \\
&+ \left(\frac{3e^2}{2^3} - \frac{3^2 . 5e^4}{2^7} + \frac{7 . 3^4 e^6}{2^{10} . 5} - \frac{3^6 e^8}{2^{13} . 5} + \frac{3^8 . 11e^{10}}{2^{17} . 5 . 7} - \ldots\ldots\right)\cos 3M \\
&+ \left(\frac{e^3}{3} - \frac{2e^5}{5} + \frac{2^3 e^7}{3^2 . 5} - \frac{2^3 e^9}{3^3 . 7} + \frac{2e^{11}}{3^2 . 5 . 7} - \ldots\ldots\right)\cos 4M \\
&+ \left(\frac{5^3 e^4}{2^7 . 3} - \frac{5^4 . 7e^6}{2^{10} . 3^2} + \frac{5^6 e^8}{2^{13} . 7} - \frac{5^8 . 11e^{10}}{2^{13} . 3^3 . 7} + \ldots\ldots\right)\cos 5M \\
&+ \left(\frac{3^3 e^5}{2^4 . 5} - \frac{3^4 e^7}{2^2 . 5 . 7} + \frac{3^6 e^9}{2^5 . 7} - \frac{3^8 e^{11}}{2^7 . 5 . 7} + \ldots\ldots\right)\cos 6M \\
&+ \left(\frac{7^5 e^6}{2^{10} . 3^2 . 5} - \frac{7^6 e^8}{2^{15} . 5} + \frac{7^8 . 11e^{10}}{2^{18} . 3^4 . 5 . 7} - \ldots\ldots\right)\cos 7M \\
&+ \left(\frac{2^7 e^7}{3^2 . 5 . 7} - \frac{2^9 e^9}{3^4 . 7} + \frac{2^{12} e^{11}}{3^3 . 5^2 . 7} - \ldots\ldots\right)\cos 8M \\
&+ \left(\frac{3^{12} e^8}{2^{15} . 5 . 7} - \frac{3^{14} . 11e^{10}}{2^{18} . 5^2 . 7} + \ldots\ldots\right)\cos 9M \\
&+ \left(\frac{5^7 e^9}{2^8 . 3^4 . 7} - \frac{5^9 e^{11}}{2^7 . 3^3 . 7 . 11} + \ldots\ldots\right)\cos 10M \\
&+ \left(\frac{11^9 e^{10}}{2^{18} . 3^4 . 5^2 . 7} - \ldots\ldots\right)\cos 11M \\
&+ \left(\frac{2 . 3^9 e^{11}}{5^2 . 7 . 11} - \ldots\ldots\right)\cos 12M \\
&+ \ldots\ldots
\end{aligned}
$$

A check in this and the next series is obtained by putting M=0 when the second member reduces to 1 as it should.

$$
\begin{aligned}
\cos 2E = & \left(\quad - e + \frac{e^3}{2^2 \cdot 3} - \frac{e^5}{2^7 \cdot 3} + \frac{e^7}{2^9 \cdot 3^2 \cdot 5} - \frac{e^9}{2^{14} \cdot 3^3 \cdot 5} + \dots \right) \cos M \\
& + \left(1 - e^2 + \frac{5e^4}{2^3 \cdot 3} - \frac{7e^6}{2^3 \cdot 3^2 \cdot 5} + \frac{e^8}{2^6 \cdot 3 \cdot 5} - \frac{11e^{10}}{2^6 \cdot 3^3 \cdot 5^2 \cdot 7} + \dots \right) \cos 2M \\
& + \left(e - \frac{3^2 e^3}{2^3} + \frac{3^5 e^5}{2^7 \cdot 5} - \frac{3^4 e^7}{2^8 \cdot 5} + \frac{3^8 e^9}{2^{14} \cdot 7} - \dots \right) \cos 3M \\
& + \left(e^2 - \frac{2^2 e^4}{3} + \frac{2^7 \cdot 7e^6}{3^2 \cdot 5} - \frac{2^4 e^8}{3 \cdot 5 \cdot 7} + \frac{2 \cdot 11e^{10}}{3^3 \cdot 5 \cdot 7} - \dots \right) \cos 4M \\
& + \left(\frac{5^2 e^3}{2^3 \cdot 3} - \frac{5^4 e^5}{2^7 \cdot 3} + \frac{5^6 e^7}{2^8 \cdot 3^2 \cdot 7} - \frac{5^9 e^9}{2^{15} \cdot 3^3 \cdot 7} + \dots \right) \cos 5M \\
& + \left(\frac{3^2 e^4}{2^3} - \frac{3^4 e^6}{2^3 \cdot 5} + \frac{3^8 e^8}{2^7 \cdot 5 \cdot 7} - \frac{3^5 \cdot 11e^{10}}{2^7 \cdot 5 \cdot 7} + \dots \right) \cos 6M \\
& + \left(\frac{7^4 e^5}{2^7 \cdot 3 \cdot 5} - \frac{7^6 e^7}{2^{10} \cdot 3^2 \cdot 5} + \frac{7^8 e^9}{2^{15} \cdot 3^4} - \dots \right) \cos 7M \\
& + \left(\frac{2^6 e^6}{3^2 \cdot 5} - \frac{2^{10} e^8}{3^2 \cdot 5 \cdot 7} + \frac{2^{12} \cdot 11e^{10}}{3^4 \cdot 5^2 \cdot 7} - \dots \right) \cos 8M \\
& + \left(\frac{3^{10} e^7}{2^{10} \cdot 5 \cdot 7} - \frac{3^{14} e^9}{2^{15} \cdot 5 \cdot 7} + \dots \right) \cos 9M \\
& + \left(\frac{5^6 e^8}{2^7 \cdot 3^2 \cdot 7} - \frac{5^8 e^{10}}{2^7 \cdot 3^4 \cdot 7} + \dots \right) \cos 10M \\
& + \left(\frac{11^8 e^9}{2^{15} \cdot 3^4 \cdot 5 \cdot 7} - \dots \right) \cos 11M \\
& + \left(\frac{2 \cdot 3^5 e^{10}}{5^2 \cdot 7} - \dots \right) \cos 12M \\
& + \dots
\end{aligned}
$$

and so on.

Putting $i=1$ in (14), multiplying the resulting series by e, and substituting in (1), we have the following converging series for the direct computation of E.

$$
\begin{aligned}
E = M &+ \left(e - \frac{e^3}{2^3} + \frac{e^5}{2^6 . 3} - \frac{e^7}{2^{10} . 3^2} + \frac{e^9}{2^{18} . 3^2 . 5} - \frac{e^{11}}{2^{17} . 3^3 . 5^2} + \ldots\right) \sin M \\
&+ \left(\frac{e^2}{2} - \frac{e^4}{2 . 3} + \frac{e^6}{2^4 . 3} - \frac{e^8}{2^4 . 3^2 . 5} + \frac{e^{10}}{2^7 . 3^3 . 5} - \frac{e^{12}}{2^7 . 3^3 . 5^2 . 7} + \ldots\right) \sin 2M \\
&+ \left(\frac{3e^3}{2^3} - \frac{3^3 e^5}{2^7} + \frac{3^5 e^7}{2^{10} . 5} - \frac{3^5 e^9}{2^{13} . 5} + \frac{3^7 e^{11}}{2^7 . 5 . 7} - \ldots\ldots\right) \sin 3M \\
&+ \left(\frac{e^4}{3} - \frac{2^2 e^6}{3 . 5} + \frac{2^2 e^8}{3^2 . 5} - \frac{2^4 e^{10}}{3^3 . 5 . 7} + \frac{2e^{12}}{3^3 . 5 . 7} - \ldots\ldots\right) \sin 4M \\
&+ \left(\frac{5^3 e^5}{2^7 . 3} - \frac{5^5 e^7}{2^{10} 3^2} + \frac{5^7 e^9}{2^{13} . 3^2 . 7} - \frac{5^9 e^{11}}{2^{18} . 3^3 . 7} + \ldots\ldots\right) \sin 5M \\
&+ \left(\frac{3^3 e^6}{2^4 . 5} - \frac{3^5 e^8}{2^4 . 5 . 7} + \frac{3^7 e^{10}}{2^8 . 5 . 7} - \frac{3^6 e^{12}}{2^8 . 5 . 7} + \ldots\ldots\right) \sin 6M \\
&+ \left(\frac{7^5 e^7}{2^{10} . 3^2 . 5} - \frac{7^7 e^9}{2^{15} . 3^3 . 5} + \frac{7^9 e^{11}}{2^{18} . 3^4 . 5} - \ldots\ldots\right) \sin 7M \\
&+ \left(\frac{2^7 e^8}{3^2 . 5 . 7} - \frac{2^{11} e^{10}}{3^4 . 5 . 7} + \frac{2^{13} e^{12}}{3^4 . 5^2 . 7} - \ldots\ldots\right) \sin 8M \\
&+ \left(\frac{3^{12} e^9}{2^{15} . 5 . 7} - \frac{3^{14} e^{11}}{2^{18} . 5^2 . 7} + \ldots\ldots\right) \sin 9M \\
&+ \left(\frac{5^7 e^{10}}{2^8 . 3^4 . 7} - \frac{5^9 e^{12}}{2^8 . 3^4 . 7 . 11} + \ldots\ldots\right) \sin 10M \\
&+ \left(\frac{11^9 e^{11}}{2^{18} . 3^4 . 5^2 . 7} - \ldots\ldots\right) \sin 11M \\
&+ \left(\frac{2 . 3^6 e^{12}}{5^2 . 7 . 11} - \ldots\ldots\right) \sin 12M \\
&+ \ldots\ldots
\end{aligned}
$$

[illegible] in logarithms, [illegible] planets.

[illegible]

[illegible]

For finding the true anomaly we shall have

$\tan \frac{1}{2} v = [\text{illegible}] \tan \frac{1}{2} E$

Example. Let M = [illegible]

[illegible]

Venus.

$e = \cdot 0068433[\text{illegible}]$ $e'' = 1411''\cdot 534$

$E = M + [3\cdot 1496888] \sin M + [0\cdot 6839207] \sin 2M$
$+ [8\cdot 3942434] \sin 3M + [6\cdot 1783520] \sin 4M$

$\tan \frac{1}{2} v = [0\cdot 0029720] \tan \frac{1}{2} E.$

The Earth.

$e = \cdot 0167711$ $e'' = 3459''\cdot 287$

$E = M + [3\cdot 5380714] \sin M + [1\cdot 4624774] \sin 2M$
$+ [9\cdot 5020725] \sin 3M + [7\cdot 7354525] \sin 4M$

$\tan \frac{1}{2} v = [0\cdot 0072842] \tan \frac{1}{2} E.$

Example. Let $M = 71°$.

$E = 71° + 54' \; 30''\cdot 7060 + 17''\cdot 8574 - 0''\cdot 1987 - 0''\cdot 00527$
$= 71° \; 54' \; 48''\cdot 359.$

[illegible]

Check.

$$E = M + e'' \sin E$$
$$= 71^\circ + 3288''\cdot359 = 71^\circ\ 54'\ 48''\cdot359.$$

Mars.

$e = \cdot09326113$ $e'' = 19236''\cdot5$

$$E = M + [4\cdot2836536] \sin M + [2\cdot9515369] \sin 2M$$
$$+ [1\cdot7954344] \sin 3M + [0\cdot7130829] \sin 4M$$
$$+ [9\cdot6715855] \sin 5M + [8\cdot6560435] \sin 6M$$
$$+ [7\cdot6585193] \sin 7M +$$
$$\tan \tfrac{1}{2} \nu = [0\cdot0406208] \tan \tfrac{1}{2} E.$$

Jupiter.

$e = \cdot0482519$ $e'' = 9952''\cdot67$

$$E = M + [3\cdot9978131] \sin M + [2\cdot3800869] \sin 2M$$
$$+ [0\cdot9384309] \sin 3M + [9\cdot5706569] \sin 4M$$
$$+ [8\cdot2435235] \sin 5M + [6\cdot9424833] \sin 6M$$
$$\tan \tfrac{1}{2} \nu = [0\cdot0209718] \tan \tfrac{1}{2} E.$$

Saturn.

$e = \cdot0559428$ $e'' = 11539''\cdot02$

$$E = M + [4\cdot0619992] \sin M + [2\cdot5084302] \sin 2M$$
$$+ [1\cdot1309242] \sin 3M + [9\cdot8271927] \sin 4M$$
$$+ [8\cdot5643061] \sin 5M + [7\cdot3274187] \sin 6M$$
$$\tan \tfrac{1}{2} \nu = [0\cdot0243210] \tan \tfrac{1}{2} E.$$

Uranus.

$e = \cdot0463592$ $e'' = 9562''\cdot29$

$$E = M + [3\cdot9804453] \sin M + [2\cdot3453568] \sin 2M$$
$$+ [0\cdot8917040] \sin 3M + [9\cdot5011044] \sin 4M$$
$$+ [8\cdot1567170] \sin 5M + [6\cdot8383189] \sin 6M$$
$$\tan \tfrac{1}{2} \nu = [0\cdot0201480] \tan \tfrac{1}{2} E.$$

Neptune.

$e = \cdot0089903$ $e'' = 1854''\cdot38$

$$E = M + [3\cdot2681948] \sin M + [0\cdot9209318] \sin 2M$$
$$+ [8\cdot7497592] \sin 3M + [6\cdot6523734] \sin 4M$$
$$\tan \tfrac{1}{2} \nu = [0\cdot0039045] \tan \tfrac{1}{2} E.$$

Equation of the Centre.

From the theory of elliptic motion we have

$$\frac{dv}{dt}=\frac{h}{r^2},$$

where h=half the area described in a unit of time; therefore

$$\frac{T}{\pi ab}=\frac{2}{h};$$

whence

$$h=\frac{2\pi ab}{T};$$

therefore

$$\frac{dv}{dt}=\frac{2\pi ab}{Tr^2},$$

and

$$\frac{dM}{dt}=\frac{2\pi}{T}.$$

Now,

$$\frac{dv}{dM}=\frac{dv}{dt}\cdot\frac{dt}{dM}=\frac{ab}{r^2};$$

but

$$b=a\sqrt{1-e^2},$$

and

$$r=a\,(1-e\cos E);$$

therefore

$$\frac{dv}{dM}=\frac{\sqrt{1-e^2}}{(1-e\cos E)^2} \qquad (15)$$

Developing the second member by the binomial theorem, and changing the powers of cos E to the cosines of multiples of E, we have

$$
\begin{aligned}
\frac{dv}{dM} = \; & (1-e^2)^{\frac{1}{2}}\,(1-e\cos E)^{-2} \\
= \; & \left(1 + e^2 + e^4 + e^6 + e^8 + e^{10} + e^{12} + \ldots\right) \\
& + 2\left(e + e^3 + e^5 + e^7 + e^9 + e^{11} + \ldots\right)\cos E \\
& + \left(\frac{3}{2}e^2 + \frac{7}{2^3}e^4 + \frac{59}{2^5}e^6 + \frac{121}{2^6}e^8 + \frac{491}{2^8}e^{10} + \frac{991}{2^9}e^{12} + \ldots\right)\cos 2E \\
& + \left(e^3 + \frac{11}{2^3}e^5 + \frac{25}{2^4}e^7 + \frac{107}{2^6}e^9 + \frac{223}{2^7}e^{11} + \ldots\right)\cos 3E \\
& + \left(\frac{5}{2^3}e^4 + e^6 + \frac{79}{2^6}e^8 + \frac{89}{2^6}e^{10} + \frac{3073}{2^{11}}e^{12} + \ldots\right)\cos 4E \\
& + \left(\frac{3}{2^3}e^5 + \frac{11}{2^4}e^7 + \frac{59}{2^6}e^9 + \frac{281}{2^8}e^{11} + \ldots\right)\cos 5E \\
& + \left(\frac{7}{2^5}e^6 + \frac{29}{2^6}e^8 + \frac{337}{2^9}e^{10} + \frac{849}{2^{10}}e^{12} + \ldots\right)\cos 6E \\
& + \left(\frac{1}{2^3}e^7 + \frac{37}{2^7}e^9 + \frac{29}{2^8}e^{11} + \ldots\right)\cos 7E \\
& + \left(\frac{9}{2^7}e^8 + \frac{23}{2^7}e^{10} + \frac{155}{2^9}e^{12} + \ldots\right)\cos 8E \\
& + \left(\frac{5}{2^7}e^9 + \frac{7}{2^6}e^{11} + \ldots\right)\cos 9E \\
& + \left(\frac{11}{2^9}e^{10} + \frac{121}{2^{11}}e^{12} + \ldots\right)\cos 10E \\
& + \left(\frac{3}{2^9}e^{11} + \ldots\right)\cos 11E \\
& + \left(\frac{13}{2^{11}}e^{12} + \ldots\right)\cos 12E
\end{aligned}
$$

Substituting the values of cos E, cos 2E, &c., obtained from (13), multiplying by dM and integrating, we have, after putting C, the equation of the centre, $=\nu - M$

$$
\begin{aligned}
C = &+\left(2e - \frac{e^3}{2^2} + \frac{5e^5}{2^5 \cdot 3} + \frac{107e^7}{2^9 \cdot 3^2} + \frac{6217e^9}{2^{15} \cdot 3^2 \cdot 5} + \frac{565879e^{11}}{2^{16} \cdot 3^3 \cdot 5^2} + \ldots\right)\sin M \\
&+\left(\frac{5e^2}{2^2} - \frac{11e^4}{2^3 \cdot 3} + \frac{17e^6}{2^6 \cdot 3} + \frac{43e^8}{2^7 \cdot 3^2 \cdot 5} + \frac{677e^{10}}{2^9 \cdot 3^3 \cdot 5} + \frac{7237e^{12}}{2^{10} \cdot 3^3 \cdot 5 \cdot 7} + \ldots\right)\sin 2M \\
&+\left(\frac{13e^3}{2^2 \cdot 3} - \frac{43e^5}{2^6} + \frac{95e^7}{2^9} - \frac{973e^9}{2^{12} \cdot 3 \cdot 5} + \frac{19503e^{11}}{2^{16} \cdot 5 \cdot 7} + \ldots\right)\sin 3M \\
&+\left(\frac{103e^4}{2^5 \cdot 3} - \frac{451e^6}{2^5 \cdot 3 \cdot 5} + \frac{4123e^8}{2^8 \cdot 3^2 \cdot 5} - \frac{1619e^{10}}{2^7 \cdot 3^3 \cdot 7} + \frac{111929e^{12}}{2^{13} \cdot 3^3 \cdot 5 \cdot 7} + \ldots\right)\sin 4M \\
&+\left(\frac{1097e^5}{2^6 \cdot 3 \cdot 5} - \frac{5957e^7}{2^9 \cdot 3^2} + \frac{164921e^9}{2^{13} \cdot 3^2 \cdot 7} - \frac{4305913e^{11}}{2^{17} \cdot 3^3 \cdot 7} + \ldots\right)\sin 5M \\
&+\left(\frac{1223e^6}{2^6 \cdot 3 \cdot 5} - \frac{7913e^8}{2^7 \cdot 5 \cdot 7} + \frac{7751e^{10}}{2^{10} \cdot 7} - \frac{82021e^{12}}{2^{11} \cdot 3 \cdot 5 \cdot 7} + \ldots\right)\sin 6M \\
&+\left(\frac{47273e^7}{2^9 \cdot 3^2 \cdot 7} - \frac{1773271e^9}{2^{14} \cdot 3^2 \cdot 5} + \frac{935213039e^{11}}{2^{17} \cdot 3^4 \cdot 5} - \ldots\right)\sin 7M \\
&+\left(\frac{556403e^8}{2^{10} \cdot 3^2 \cdot 5 \cdot 7} - \frac{1182827e^{10}}{2^7 \cdot 3^4 \cdot 5 \cdot 7} + \frac{324319490e^{12}}{2^{13} \cdot 3^4 \cdot 5 \cdot 7} - \ldots\right)\sin 8M \\
&+\left(\frac{10661993e^9}{2^{14} \cdot 3^2 \cdot 5 \cdot 7} - \frac{101836961e^{11}}{2^{17} \cdot 5^2 \cdot 7} + \ldots\right)\sin 9M \\
&+\left(\frac{7281587e^{10}}{2^{10} \cdot 3^4 \cdot 5 \cdot 7} - \frac{769805651e^{12}}{2^{13} \cdot 3^4 \cdot 5 \cdot 7 \cdot 11} + \ldots\right)\sin 10M \\
&+\left(\frac{62929017101e^{11}}{2^{17} \cdot 3^4 \cdot 5^2 \cdot 7 \cdot 11} - \ldots\right)\sin 11M \\
&+\left(\frac{7218065e^{12}}{2^{13} \cdot 3 \cdot 7 \cdot 11} - \ldots\right)\sin 12M
\end{aligned}
$$

Greatest Equation of the Centre.

When the equation of the centre has its maximum value, $d(\nu - \mathrm{M}) = 0$ or $d\nu = d\mathrm{M}$; therefore, from (15), we have

$$\cos \mathrm{E} = \frac{1-(1-e^2)^{\frac{1}{4}}}{e}$$

$$= \frac{e}{2^2} + \frac{3e^3}{2^5} + \frac{7e^5}{2^7} + \frac{77e^7}{2^{11}} + \ldots$$

and

$$\sin \mathrm{E} = 1 - \frac{e^2}{2^5} - \frac{49e^4}{2^{11}} - \frac{1233e^6}{2^{16}} - \ldots \tag{16}$$

whence

$$\sin 2\,\mathrm{E} = \frac{e}{2} + \frac{11e^3}{2^6} + \frac{375e^5}{2^{12}} + \frac{7587e^7}{2^{17}} + \ldots$$

$$\sin 3\,\mathrm{E} = -1 + \frac{9e^2}{2^5} + \frac{417e^4}{2^{11}} + \frac{1087e^6}{2^{18}} + \ldots$$

&c., &c.

Any one of these will give the eccentric anomaly when the equation of the centre is a maximum. Developing

$$\tan \tfrac{1}{2}\nu = \sqrt{\frac{1+e}{1-e}} \,.\, \tan \tfrac{1}{2}\mathrm{E}$$

into a series, we have

$$\nu = \mathrm{E} + 2\tan\frac{\phi}{2}\sin \mathrm{E} + \tan^2\frac{\phi}{2}\sin 2\mathrm{E} + \frac{2}{3}\tan^3\frac{\phi}{2}\sin 3\mathrm{E} + \text{ \&c.},$$

where

$$\tan\frac{\phi}{2} = \frac{1-(1-e^2)^{\frac{1}{2}}}{e}$$

$$= \frac{e}{2} + \frac{e^3}{2^3} + \frac{e^5}{2^4} + \frac{5e^7}{2^7} + \text{ \&c.}$$

Substituting the values of $\sin \mathrm{E}$, $\sin 2\mathrm{E}$, &c., $\tan\frac{\phi}{2}$, $\tan^2\frac{\phi}{2}$ &c., we find

$$\nu = \mathrm{E} + e + \frac{25}{2^5 \cdot 3}e^3 + \frac{1443}{2^{11} \cdot 5}e^5 + \frac{43069}{2^{16} \cdot 7}e^7 + \ldots \tag{17}$$

Multiplying the second series of (16) by e, and substituting in (1), we get

$$M=E-e+\frac{e^3}{2^6}+\frac{49}{2^{11}}e^5+\frac{1233}{2^{16}}e^7+\ldots \qquad (18)$$

Subtracting (18) from (17), we have

$$C=v-M$$

$$=2e+\frac{11}{2^4 \cdot 3}e^3+\frac{599}{2^{10} \cdot 5}e^5+\frac{17219}{2^{15} \cdot 7}e^7+\ldots \qquad (19)^*$$

Reverting this series we have

$$e=\frac{C}{2}-\frac{11}{2^7 \cdot 3}C^3-\frac{587}{2^{16} \cdot 3 \cdot 5}C^5-\frac{40583}{2^{23} \cdot 3^2 \cdot 5 \cdot 7}C^7-\ldots \qquad (20)$$

The Radius Vector.

By the properties of the ellipse we have $r=a\,(1-e\cos E)$, in which substitute the values of $\cos E$; we thus deduce the following series, a check upon which is obtained by putting $M=0$, when it reduces to $\frac{r}{a}=1-e$.

---

* Delambre, in his *Astronomy*, vol. ii. p. 55, has given this series correctly, but farther down on the same page he committed an error in reducing the term in e^7, which he gave as $\frac{17219}{2^{16} \cdot 7}e^7$. He also gave the second term of series (20) incorrectly as $-\frac{11}{2^4 \cdot 3}C^3$. Both of these incorrect values were copied by Baily in his "Astronomical Tables and Formulæ," and from him by several other writers on Astronomy. Mr. Farrel in the *Monthly Notices* of the Royal Astronomical Society, June 1860, corrects Baily as to series (20), but at the same time adopts Delambre's incorrect value of the last term of (19), and computes accordingly.

$$
\begin{aligned}
\frac{r}{a} = &+\left(1 + \frac{e^2}{2}\right) \\
&+\left(-e + \frac{3}{2^3}e^3 - \frac{5}{2^6 . 3}e^5 + \frac{7}{2^{10} . 3^2}e^7 - \frac{1}{2^{14} . 5}e^9 + \frac{11}{2^{17} . 3^3 . 5^2}e^{11} - \cdots\right)\cos M \\
&+\left(-\frac{e^2}{2} + \frac{1}{3}e^4 - \frac{1}{2^4}e^6 + \frac{1}{2^2 . 3^2 . 5}e^8 - \frac{1}{2^7 . 3^3}e^{10} + \frac{1}{2^6 . 3^2 . 5^2 . 7}e^{12} - \cdots\right)\cos 2M \\
&+\left(-\frac{3}{2^3}e^3 + \frac{3^2 . 5}{2^7}e^5 - \frac{7 . 3^4}{2^{10} . 5}e^7 + \frac{3^6}{2^{13} . 5}e^9 - \frac{3^6 . 11}{2^{17} . 5 . 7}e^{11} + \cdots\right)\cos 3M \\
&+\left(-\frac{1}{3}e^4 + \frac{2}{5}e^6 - \frac{2^3}{3^2 . 5}e^8 + \frac{2^3}{3^2 . 7}e^{10} - \frac{2}{3^2 . 5 . 7}e^{12} + \cdots\right)\cos 4M \\
&+\left(-\frac{5^3}{2^7 . 3}e^5 + \frac{5^4 . 7}{2^{10} . 3^2}e^7 - \frac{5^6}{2^{13} . 7}e^9 + \frac{5^8 . 11}{2^{18} . 3^3 . 7}e^{11} - \cdots\right)\cos 5M \\
&+\left(-\frac{3^3}{2^4 . 5}e^6 + \frac{3^4}{2^2 . 5 . 7}e^8 - \frac{3^6}{2^5 . 7}e^{10} + \frac{3^6}{2^7 . 5 . 7}e^{12} - \cdots\right)\cos 6M \\
&+\left(-\frac{7^5}{2^{10} . 3^2 . 5}e^7 + \frac{7^6}{2^{15} . 5}e^9 - \frac{7^8 . 11}{2^{18} . 3^4 . 5 . 7}e^{11} + \cdots\right)\cos 7M \\
&+\left(-\frac{2^7}{3^2 . 5 . 7}e^8 + \frac{2^9}{3^4 . 7}e^{10} - \frac{2^{12}}{3^3 . 5^2 . 7}e^{12} + \cdots\right)\cos 8M \\
&+\left(-\frac{3^{12}}{2^{15} . 5 . 7}e^9 + \frac{3^{14} . 11}{2^{18} . 5^2 . 7}e^{11} - \cdots\right)\cos 9M \\
&+\left(-\frac{5^7}{2^8 . 3^4 . 7}e^{10} + \frac{5^8}{2^7 . 3^3 . 7 . 11}e^{12} - \cdots\right)\cos 10M \\
&+\left(-\frac{11^9}{2^{18} . 3^4 . 5^2 . 7}e^{11} + \cdots\right)\cos 11M \\
&+ -\frac{2 . 3^8}{5^2 . 7 . 11}e^{12} + \cdots)\cos 12M
\end{aligned}
$$

The Logarithm of the Radius Vector.

The logarithm of the radius vector may be expressed in terms of the eccentricity and mean anomaly, by developing the equation $\frac{r}{a} = 1 - e \cos E$ by the logarithmic series, thus,

$$\log\frac{r}{a} = -e\cos E - \frac{e^2}{2}\cos^2 E - \frac{e^3}{3}\cos^3 E \ -\&c.$$

Transforming this series from powers of cos E to the cosines of multiples of E we obtain the following series, which expresses the logarithm of $\frac{r}{a}$ in terms of the eccentricity and the eccentric anomaly.

$$\begin{aligned}
\log\frac{r}{a} = &-\left(\frac{e^2}{2^2} + \frac{3e^4}{2^5} + \frac{5e^6}{2^5 . 3} + \frac{5 . 7e^8}{2^{10}} + \frac{3^2 . 7e^{10}}{2^9 . 5} + \frac{7 . 11e^{12}}{2^{12}} + \ldots\right)\\
&-\left(e + \frac{e^3}{2^2} + \frac{e^5}{2^3} + \frac{5e^7}{2^6} + \frac{7e^9}{2^7} + \frac{3 . 7e^{11}}{2^9} + \ldots\right)\cos E\\
&-\left(\frac{e^2}{2^2} + \frac{e^4}{2^3} + \frac{5e^6}{2^6} + \frac{7e^8}{2^7} + \frac{3 . 7e^{10}}{2^9} + \frac{3 . 11e^{12}}{2^{10}} + \ldots\right)\cos 2E\\
&-\left(\frac{e^3}{2^2 . 3} + \frac{e^5}{2^4} + \frac{3e^7}{2^6} + \frac{7e^9}{2^6 . 3} + \frac{3 . 5e^{11}}{2^9} + \ldots\ldots\right)\cos 3E\\
&-\left(\frac{e^4}{2^5} + \frac{e^6}{2^5} + \frac{7e^8}{2^8} + \frac{3e^{10}}{2^7} + \frac{3 . 5 . 11e^{12}}{2^{13}} + \ldots\ldots\right)\cos 4E\\
&-\left(\frac{e^5}{2^4 . 5} + \frac{e^7}{2^6} + \frac{e^9}{2^6} + \frac{3 . 5e^{11}}{2^{10}} + \ldots\ldots\right)\cos 5E\\
&-\left(\frac{e^6}{2^6 . 3} + \frac{e^8}{2^7} + \frac{3^2e^{10}}{2^{10}} + \frac{5 . 11e^{12}}{2^{11} . 3} + \ldots\ldots\right)\cos 6E\\
&-\left(\frac{e^7}{2^6 . 7} + \frac{e^9}{2^8} + \frac{5e^{11}}{2^{10}} + \ldots\ldots\right)\cos 7E\\
&-\left(\frac{e^8}{2^{10}} + \frac{e^{10}}{2^9} + \frac{11e^{12}}{2^{12}} + \ldots\ldots\right)\cos 8E\\
&-\left(\frac{e^9}{2^8 . 3^2} + \frac{e^{11}}{2^{10}} + \ldots\ldots\right)\cos 9E\\
&-\left(\frac{e^{10}}{2^{10} . 5} + \frac{e^{12}}{2^{11}} + \ldots\ldots\right)\cos 10E\\
&-\left(\frac{e^{11}}{2^{10} . 11} + \ldots\ldots\right)\cos 11E\\
&-\left(\frac{e^{12}}{2^{13} . 3} + \ldots\ldots\right)\cos 12E
\end{aligned}$$

Substituting the values of cos E, cos 2E, &c., we have

$$
\begin{aligned}
\log\frac{r}{a} = & +\frac{e^2}{2^2} + \frac{e^4}{2^5} + \frac{e^6}{2^5.3} + \frac{5e^8}{2^{10}} + \frac{7e^{10}}{2^9.5} + \ldots \\
& +\left(-e + \frac{3e^3}{2^3} + \frac{e^5}{2^6} + \frac{127e^7}{2^{10}.3^2} + \frac{1741e^9}{2^{14}.3.5} + \ldots\right)\cos M \\
& +\left(-\frac{3e^2}{2^2} + \frac{11e^4}{2^3.3} - \frac{3e^6}{2^6} + \frac{3^2e^8}{2^7.5} + \frac{349e^{10}}{2^9.3^2.5} + \ldots\right)\cos 2M \\
& +\left(-\frac{17e^3}{2^3.3} + \frac{7.11e^5}{2^7} - \frac{743e^7}{2^{10}.5} + \frac{3539e^9}{2^{13}.3.5} - \ldots\ldots\ldots\right)\cos 3M \\
& +\left(-\frac{71e^4}{2^5.3} + \frac{129e^6}{2^5.5} - \frac{387e^8}{2^8.5} + \frac{8639e^{10}}{2^7.3^2.5.7} - \ldots\ldots\ldots\right)\cos 4M \\
& +\left(-\frac{523e^5}{2^7.5} + \frac{10039e^7}{2^{10}.3^2} - \frac{94739e^9}{2^{13}.3.7} + \ldots\ldots\ldots\ldots\right)\cos 5M \\
& +\left(-\frac{899e^6}{2^6.3.5} + \frac{6617e^8}{2^7.5.7} - \frac{33571e^{10}}{2^{10}.5.7} + \ldots\ldots\ldots\ldots\right)\cos 6M \\
& +\left(-\frac{355081e^7}{2^{10}.3^2.5.7} + \frac{986099e^9}{2^{15}.3.5} - \ldots\ldots\ldots\ldots\ldots\right)\cos 7M \\
& +\left(-\frac{47259e^8}{2^{10}.5.7} + \frac{3959051e^{10}}{2^9.3^4.5.7} - \ldots\ldots\ldots\ldots\ldots\right)\cos 8M \\
& +\left(-\frac{165410017e^9}{2^{16}.3^2.5.7} + \ldots\ldots\ldots\ldots\ldots\ldots\right)\cos 9M \\
& +\left(-\frac{5719087e^{10}}{2^{10}.3^4.5.7} + \ldots\ldots\ldots\ldots\ldots\ldots\right)\cos 10M
\end{aligned}
$$

Check. Putting M=0, it reduces to

$$\log \frac{r}{a} = -\left(e + \frac{e^2}{2} + \frac{e^3}{3} + \frac{e^4}{4} + \ \ldots \ + \frac{e^{10}}{10} + \ \ldots\right)$$

as it should.

When the eccentricity is large, as in the case of the orbits of comets and some of the asteroids, the preceding series for the computation of the eccentric anomaly are not sufficiently converging. In that case the following method may be used:

In the equation $M = E - e \sin E$, let $E = M + x$, that is $x = e \sin E$; then we shall have

$$M = M + x - e \sin (M + x)$$

or

$$\begin{aligned} x &= e \sin M \cos x + e \sin x \cos M \\ &= e \sin M \left(1 - \frac{x^2}{2} + \ \ldots\right) + e \cos M \left(x - \frac{x^3}{6} + \ \ldots\right) \end{aligned}$$

or

$$e \sin M = (1 - e \cos M)x + \frac{e \sin M}{2} x^2 + \frac{e \cos M}{6} x^3 - \ \ldots$$

Reverting this series, we have

$$\begin{aligned} e \sin E &= x \\ &= \frac{e \sin M}{1 - e \cos M} - \tfrac{1}{2}\left(\frac{e \sin M}{1 - e \cos M}\right)^3 + \ \ldots \end{aligned}$$

therefore,

$$\begin{aligned} E &= M + e \sin E \\ &= M + \frac{e \sin M}{1 - e \cos M} - \tfrac{1}{2}\left(\frac{e \sin M}{1 - e \cos M}\right)^3 + \ \ldots \end{aligned}$$

It will generally be sufficient to use only the first two terms of this series which will give the first approximate value of E, which we will denote by E′. With this approximate value compute

$$M' = E' - e \sin E';$$

then, by subtraction, we have

$$\begin{aligned} M - M' &= E - E' - e (\sin E - \sin E') \\ &= E - E' - e (E - E') \cos E', \text{ approximately}; \end{aligned}$$

whence

$$E = E' + \frac{M - M'}{1 - e \cos E'},$$

which is a more accurate value of E.

The last process may be repeated as often as necessary, but unless the first approximation is very far from the truth it will not be necessary to proceed with the computation farther than we have indicated.

This is the same as the method recommended by the late Professor Encke in the *Berliner Astronomisches Jahrbuch*, 1838, and is substantially the same as that given by Gauss in his *Theoria Motus Corporum Cœlestium*, art. ii.

Note on Dr. Morrison's Paper. By Professor J. C. Adams, M.A., F.R.S.

The reference to Hansen's paper should be made to *Abhandlungen der Sächsischen Gesellschaft der Wissenschaften*, Band iv. p. 249, instead of to Band ii. as stated by Dr. Morrison.

In this paper Hansen's object is not merely to express the coefficients of the series which gives the eccentric anomaly in powers of e, otherwise this might have been done much more simply in the following manner.

Calling g the mean, and x the eccentric anomaly, we have

$$g = x - e \sin x,$$

or

$$x = g + e \sin x,$$

which is in the proper form for the application of Lagrange's theorem for developing x or any function of x in terms of g and ascending powers of e.

Hence we have

$$x = g + e \sin g + \frac{e^2}{1.2}\frac{d}{dg}(\sin^2 g) + \frac{e^3}{1.2.3}\frac{d^2}{dg^2}(\sin^3 g) + \frac{e^4}{1.2.3.4}\frac{d^3}{dg^3}(\sin^4 g) + \&c.$$

whence by substituting for the powers of sin g their expressions in sines or cosines of multiples of g, and differentiating, we may readily obtain the function of g which multiplies any given power of e.

The numerical coefficient of the term in $(x-g)$ which involves

$$e^m \sin (m-2n) g$$

is

$$(-1)^n \left(\frac{m-2n}{2}\right)^{m-1} \frac{1}{(1.2\ldots n)(1.2\ldots \overline{m-n})}$$

where m is a positive integer, and n is either zero or a positive integer less than $\frac{m}{2}$, and $(1.2 \ldots n)$ is to be put $=1$, when $n=0$.

The expressions for x and for the sines of multiples of x are developed to the 12th power of e by Schubert in the appendix to Bode's *Jahrbuch* for 1820. In the same appendix Schubert likewise gives the development of the true anomaly in terms of the mean to the 13th power of e.

Oriani had already given this last-mentioned development to the 11th power of e in the appendix to the Milan "Ephemeris" for 1805.

The numerical coefficients which he finds differ in four cases from those given by Schubert, but I have recomputed the coefficients in these cases, and find that Schubert's results are correct.

There is a misprint, however, in Schubert's expression for the true anomaly at the foot of p. 230, where the coefficient of

$$e^{12} \sin 12g$$

should be

$$\frac{7218065}{2^{18}.3.7.11} \text{ instead of } \frac{7218065}{2^{13}.3^{7}.11}.$$

Delambre's formula is copied from Oriani's, and is therefore affected by the same errors, together with some additional typographical ones.

I have verified Schubert's result for (v), the true anomaly in terms of the mean, by the consideration that when $g=0$, the value of

$$\frac{dv}{dg} \text{ becomes } \frac{(1+e)^2}{(1-e^2)^{\frac{3}{2}}}$$

$$= 1+2e+\frac{5}{2}e^2+3e^3+\frac{27}{8}e^4+\frac{15}{4}e^5+\frac{65}{16}e^6+\frac{35}{8}e^7+\frac{595}{128}e^8+\frac{315}{64}e^9+\frac{1323}{256}e^{10}$$
$$+\frac{693}{128}e^{11}+\frac{5775}{1024}e^{12}+\frac{3003}{512}e^{13}+ \text{ \&c.}$$

By comparing Schubert's result with that of Dr. Morrison, we see that there are the following errata in the latter: viz. the coefficient of $e^{10} \sin 8\,M$ in the equation of the centre should be

$$-\frac{4745483}{2^{9}.3^{4}.5.7} \text{ instead of } -\frac{1182827}{2^{7}.3^{4}.5.7},$$

and the coefficient of $e^{12} \sin 10\,M$ should be

$$-\frac{76972457}{2^{11}.3^{4}.7.11} \text{ instead of } -\frac{769805651}{2^{12}.3^{4}.5.7.11}.$$

In Schubert's expression for $\frac{r}{a}$ in p. 231, which is also carried as far as e^{13}, there are the following errata, which are evidently merely typographical: viz. in the coefficient of $-\cos 3g$, instead of

$$-\frac{3^{6}.11}{2^{17}.5.7}e^{11} \text{ should be } +\frac{3^{6}.11}{2^{17}.5.7}e^{11},$$

and in the coefficient of $-\cos 12g$, instead of

$$\frac{2.3}{5^{2}.7.11}e^{12} \text{ should be } \frac{2.3^{6}}{5^{2}.7.11}e^{12}.$$

Oriani's formula for the radius vector has been examined and found correct.

A very good investigation of the general term of the expansion of the true anomaly in terms of the mean is likewise given in a paper by Mr. Greatheed, in the first volume of the "Cambridge Mathematical Journal," p. 208 (p. 228 in the second edition).

The approximate expression for the eccentric anomaly in terms of the mean given by Dr. Morrison in the latter part of his paper conincides with the first two terms of the series found in Keill's "Astronomical Lectures," p. 291 (5th edition, 1760), and the method of correcting an approximately known value which Dr. Morrison quotes from Encke is identical with Newton's method for the same purpose, which is also explained in Keill's "Lectures," p. 296 *et seq.*

On this subject reference may also be made to my paper in the *Monthly Notices* for December 1882, p. 43.

In addition to the errata already specified, the following may be noticed :—

In Oriani's formula for the equation of the centre, in the Milan "Ephemeris," 1805, pp. 14 and 15,

In the coefficient of sin $4g$,

instead of $-\frac{1367}{2^7 . 3^2 . 7}e^{10}$ read $-\frac{1619}{2^7 . 3^2 . 7}e^{10}$.

In the coefficient of sin $5g$,

instead of $-\frac{3649663}{2^{17} . 3^2 . 7}e^{11}$ read $-\frac{4305913}{2^{17} . 3^2 . 7}e^{11}$.

In the coefficient of sin $6g$,

instead of $+\frac{7751}{2^{10} . 6}e^{10}$ read $+\frac{7751}{2^{10} . 7}e^{10}$.

In the coefficient of sin $11g$,

instead of $\frac{63039512101}{2^{11} . 3^4 . 5^2 . 7 . 11}e^{11}$ read $\frac{62929017101}{2^{17} . 3^4 . 5^2 . 7 . 11}e^{11}$.

As Delambre's formula is copied from Oriani, it is affected with the same errors, and in addition to these the following errata occur :—

In the Introduction to Delambre's Solar Tables, 1806,

In the coefficient of sin g,

instead of $\frac{565879}{2^{16} . 3^2 . 5^2}e^{11}$ read $\frac{565879}{2^{16} . 3^3 . 5^2}e^{11}$.

In the coefficient of sin $6g$,

instead of $-\frac{7913}{2z . 5 . 7}e^{8}$ read $-\frac{7913}{2^7 . 5 . 7}e^{8}$.

In the coefficient of sin $7g$,

instead of $-\frac{1173271}{2^{14} . 3^2 . 5}e^{9}$ read $-\frac{1773271}{2^{14} . 3^2 . 5}e^{9}$.

And in his "Astronomy," 1814, vol. ii. p. 52,

In the coefficient of sin $2g$,

instead of $+\frac{677}{2^2 \cdot 3^3 \cdot 5}e^{10}$ read $+\frac{677}{2^9 \cdot 3^3 \cdot 5}e^{10}$.

Also in Delambre's expression for $\frac{r}{a}$ the following errata occur:—

In the Introduction to his Solar Tables, 1806,

In the coefficient of $-\cos g$,

instead of $-\frac{3}{2^2}e^3$ read $-\frac{3}{2^3}e^3$.

In the coefficient of $-\cos 5g$,

instead of $+\frac{5^6}{2^{13} \cdot 9}e^9$ read $+\frac{5^6}{2^{13} \cdot 7}e^9$.

And in his "Astronomy," 1814, vol. ii. p. 51,

In the coefficient of $-\cos 5g$,

instead of $\frac{53}{2^7 \cdot 3}e^5$ read $\frac{5^3}{2^7 \cdot 3}e^5$.

Also in Delambre's formula for the hyperbolic logarithm of the radius vector, the following errata occur:—

In the Introduction to his Solar Tables, 1806,

In the coefficient of $-\cos 2g$,

instead of $-\frac{9}{240}e^6$ read $-\frac{9}{640}e^6$.

In the coefficient of $-\cos 8g$,

instead of $\frac{47529}{2^{10} \cdot 5 \cdot 7}e^8$ read $\frac{47259}{2^{10} \cdot 5 \cdot 7}e^8$.

And in his "Astronomy," 1814, vol. ii. p. 50,

In the coefficient of $-\cos 7g$,

instead of $\frac{355081}{2^{10} \cdot 3^2 \cdot 5^7}e^7$ read $\frac{355081}{2^{10} \cdot 3^2 \cdot 5 \cdot 7}e^7$.

On the Orbit of γ Coronæ Australis. By A. M. W. Downing, M.A.

Elements of the orbit of this binary star have been published by Professor Schiaparelli in *Astronomische Nachrichten*, No. 2073, and a comparison of observed and computed places given up to the date 1875·65, from which it appears that these elements represent the series of observations made up to that date extremely well. As several more recent observations of γ *Coronæ Australis* have now been published, I have determined the corrections applicable to Schiaparelli's elements in order that the places computed from them may be brought into rather better accord with the whole series of observations extending from 1834·47 to 1880·67.

The method of computation which I have adopted is that proposed by Professor Klinkerfues (*Theoretische Astronomie*, Vorlesung 110) with Dr. Doberck's modifications, by which corrections to all the assumed elements, except the semi-axis major, are found from six normal position-angles. From a consideration of the outstanding errors of the position-angles computed from Schiaparelli's elements, the following normal places have been found:—

Epoch.	Normal Angle.	θ_c
	°	°
1835·97	35·36	35·46
1851·88	3·52	3·53
1856·34	350·62	350·55
1861·88	327·72	327·56
1876·92	250·39	250·26
1879·56	238·31	238·42

If, now, the mean anomaly at any time t be represented by

$$m + (\mu + \delta\mu)t,$$

where μ is the assumed mean annual motion, by proceeding according to the above-mentioned method the following values are found:—

$$m = +2^{\circ}{\cdot}805, \quad \text{and } \delta\mu = +0^{\circ}{\cdot}0705;$$

and the corresponding correction to the assumed value of the eccentricity is $-0{\cdot}0015$. Whence we derive

$$T = 1883{\cdot}203, \qquad P = 54{\cdot}985 \text{ years}, \qquad \text{and } e = 0{\cdot}6974.$$

True anomalies for each normal epoch are found from these values, and from these with the assumed γ, λ and ☊, the corresponding position-angles are computed. And by comparing these position-angles with the normal angles we get six equations of condition for determining corrections to γ, λ and ☊ of the form

$$\theta' + \frac{d\theta'}{d☊} . \Delta ☊ + \frac{d\theta'}{d\lambda} . \Delta\lambda + \frac{d\theta'}{d\gamma} . \Delta\gamma = \theta;$$

where θ' is the computed and θ the normal position-angle. These equations being solved by the method of least squares give

$$\gamma = 69^{\circ}\ 17', \qquad \lambda = 283^{\circ}\ 57', \qquad \text{and } ☊ = 227^{\circ}\ 23'.$$

The position-angles for the normal epochs found from these elements are given above in the column θ_c. Lastly, the semi-axis major is found from all the observations of distance (combined with the new elements) with the exception of the observation made at the date 1879·70.

The new elements are:—

$$T = 1883{\cdot}203$$
$$P = 54{\cdot}985 \text{ years}$$
$$e = 0{\cdot}6974$$
$$\gamma = 69^\circ\ 17'$$
$$\lambda = 283\ 57$$
$$\Omega = 227\ 23$$
$$a = 2''{\cdot}44$$

And the comparison with the individual annual results is as follows:—

Epoch.	Observer.	θ_o	$\theta_o - \theta_c$	ρ_o	$\rho_o - \rho_c$
		°	°	"	"
1834·47	Herschel	37·1	−1·79		
35·55	"	36·8	+0·40		
36·43	"	34·5	−0·04		
37·21	"			2·66	+0·41
37·43	"	32·7	+0·16		
47·32	Jacob	14·1	+0·03	2·30	+0·10
50·46	"	5·87	−1·19	2·29	+0·25
51·54	"	4·47	+0·05	2·26	+0·27
52·49	"	2·21	+0·29	1·90	−0·02
53·52	"	359·04	−0·06	1·83	−0·03
53·71	Powell	358·57	+0·02		
54·26	Jacob	356·16	−0·77	1·71	−0·11
54·78	Powell	355·58	+0·22		
55·77	"	352·93	+0·71		
56·44	Jacob	349·44	−0·53	1·67	−0·03
57·44	"	347·37	+0·97	1·61	−0·03
58·20	"	343·42	−0·13	1·53	−0·07
59·72	Powell	338·1	+0·26		
61·69	"	328·8	+0·32		
62·27	"	325·3	−0·33		
63·84	"	318·1	+0·38		
75·65	Schiaparelli	257·41	+0·78	1·45	−0·03
76·65	Howe	253·1	+0·94	1·67	+0·19
77·43	Schiaparelli	248·36	−0·31	1·49	+0·01
77·61	Howe	245·73	−2·11	1·37	−0·10
77·69	O. Stone	249·4	+1·92		
78·49	"	242·4	−1·35	1·22	−0·22
78·49	Howe	242·9	−0·85	1·47	+0·03
79·70	Burnham	240·0	+2·34	0·87	−0·48
80·46	Russell	233·13	−0·06	1·15	−0·09
1880·67	Hargrave	232·37	+0·54	1·32	+0·12

The corrections to Schiaparelli's elements are quite small, and perhaps of little practical importance. My chief object in bringing the subject forward is to direct attention to the circumstance that, according to these elements the periastron passage occurred in the early part of the present year, in the hope that observers in the southern hemisphere may be induced to make observations of this interesting binary before the present critical state of things has passed away.

Observations of the Companion of Sirius, made at the Dearborn Observatory, Chicago. By Professor G. W. Hough, Director.

(*Communicated by the Secretaries.*)

Date.	Sid. Time.	P.	S.	Date.	Sid. Time.	P.	S.
	h	°	"		h	°	
1880·151		48·7	9·77	1882·145	7·3	42·7	9·32
·173		52·3	9·79	·148	7·0	42·7	9·35
·181		47·8	10·05	·164	7·2	43·0	9·22
				·195	7·3	42·8	9·26
1881·206		45·2	9·47	1882·991	5·2	41·9	8·98
·260		45·7	9·62	1883·066	6·1	39·3	8·81
·269		47·3		·074	6·7	40·8	9·23
·280		44·9		·115	5·5	39·3	9·11
·288		43·3	9·71	·131	6·0	39·5	9·03
				·134	6·1	39·8	8·83
1882·085	6·0	43·8	9·35	·137	5·6	39·2	9·17
·088	6·0	43·8	9·25	·142	7·5	39·5	clouded
·102	6·0	43·1	9·27	·159	6·3	39·7	9·02
·104	7·0	43·4	9·32	·175	6·9	39·6	8·99
·109	6·5	42·9	9·32	·195	7·9	38·0	9·03

Results.

1880·168	49·6	9·87	1882·127	43·1	9·30
1881·260	45·3	9·60	1883·120	39·7	9·02

On Hell's alleged Falsification of his Observations of the Transit of Venus in 1769. By Simon Newcomb.

The story of Hell's supposed tampering with his observations of the Transit of *Venus*, made at Wardhus in 1769, is so familiar to all interested in the subject that only a brief mention of its points is necessary. It is, in substance, that he delayed publishing his observations so long as to give rise to the suspicion of intending to alter them; that he showed them to no one until

after he had received the observations made at other stations; that a cloud was thus thrown over their genuineness; that the suspicions thus excited were confirmed in 1835 through the discovery and publication by Littrow of Hell's original MS. journal, which its author had neglected to destroy; and that the examination of this journal showed numerous cases of alteration and erasure of the original observed figures, including the seconds of first interior contact, which had been completely erased and replaced by new numbers inserted with different ink at some subsequent time. And the reason for all this was supposed to be that Hell desired to publish, not his true observations, but results which should be in the best possible accordance with the observations of others.

More precise statements on some points are these:—The Transit occurred 1769, June 3; Hell's party sailed from Wardhus June 27, but meeting with delays from adverse weather, and stopping to make observations, they did not reach Drontheim until August 30. After some stay here and in Christiania, Copenhagen was reached on September 17. The observations were communicated to the Danish Academy of Sciences in November or December; the printing commenced December 13, and on January 13, 1770, Hell received twenty printed copies.* For the statement that Hell was loudly called upon for his observations before he would consent to their publication, I do not know the original authority.

I have taken advantage of a visit to the Imperial Observatory of Vienna to make, with the consent and support of its Director, Professor E. Weiss, an examination of Hell's manuscript. The result is so different from that generally accepted that it seems proper to prepare a statement on the spot, with the documents before me and the circumstances in mind, instead of waiting to make a more elaborate discussion in another place.

The document with which we are principally concerned is a thin MS. volume in folio, containing twenty-seven finely written pages, and nearly as many blank ones, bearing the heading "Observationes Astronomicæ et Cætera in Itinere litterario Viennâ Wardöehusium factæ. 1768. A. M. Hell."

This volume is assumed to be in Hell's own writing, and to be his original journal of his observations. Littrow apparently treats of it as the actual first record of Hell's observations. This seems very improbable. The pages are too large to be held in the hand at the telescope, and the figures of the observations fit too well into the record to suppose that they can be the figures first written. Indeed, it is hardly conceivable that one should have written an account of the circumstances up to the moment of first contact in so continuous a way that the figures of the observation could have been put in at the moment of observation. These figures must therefore have been copied from rough notes

* These dates are from Littrow's work, *P. Hell's Reise nach Wardoe*, Journal of Sajnovics, pp. 143–158.

of some kind made at the telescope, and put in when, after the observation, Hell had an opportunity to write up the journal.

This being admitted, the question might arise whether the journal was certainly written at Wardhus at all, and could not have been written up subsequently from rough notes. Circumstances too numerous to be detailed show that the writing was done at the station, probably at the close of each day's work or each set of observations.

In connection with this journal we have to consider Littrow's book: *P. Hell's Reise nach Wardoe bei Lapland und seine Beobachtungen des Venus-Durchganges im Jahre* 1769, *von Carl Ludwig Littrow.* (Wien, 1835.) This book contains extracts from the MS. journal above mentioned, accompanied by a copious commentary descriptive of the writing, and pointing out the alterations in the record.

Hell's own publication, of which the first edition appeared at Copenhagen in 1770, should also be compared.

A comparison of these writings in a cursory way brought out one circumstance which has always been overlooked. What Hell sent to press in December 1769 was not a transcript of this journal, but a more copious account, containing eighty-one printed pages, with only an occasional identity of language. But, with a single unimportant exception, the numbers are all printed without change from the original MS. journal, whether corrected or uncorrected in that journal. Now, this fact can be reconciled with the supposition that the printed numbers were the result of calculation from the observations of others in only a single way: the journal must have been corrected from the printed book; for it is contrary to human nature to suppose that if Hell had once set out to publish numbers derived from extraneous sources he could have failed to find occasion to correct them from time to time, as new data arrived and new computations were made, and the final numbers could have been reached only when the book was printed.

Now, it is very clear to me, and the evidence will be given presently, that nearly all the alterations were made at the station—two, at least, before the ink got dry. I therefore conclude from this general survey that *whatever the sources from which the corrections were derived, the numbers as printed by Hell were all but one or two obtained at Wardhus.*

I now go into the corrections more in detail, and begin with two bad-looking cases, having, however, no direct reference to the Transit.

I. The times of the corresponding altitudes observed on June 4 are so corrected and altered as to bring about a better agreement among the individual results. Measured by our standard, this was dishonest, but, as I have elsewhere shown, more than one astronomer of good repute in the last century considered it quite right and proper. Considering the matter in a practical and not in a moral light, I submit without discussion

the proposition that, from the fact that an observer is capable of altering the individual observations of a series made by himself to make them consistent, it does not follow that he would alter his own observations to bring them into agreement with the results of a long and laborious calculation from the not more certain observations of others.

II. Having observed the last of the above-mentioned altitudes at $10^h\ 8^m\ 18^s$ (a record which he leaves unaltered), he added, originally:—

"N.B. ante hanc positionem minuto 8 10″ mane observatum est initium eclipsis ☉, quod mihi jam 20 secundis circiter citius factum fuisse videtur." After his return to Copenhagen he altered the 10″ to 27″, and the 20 to 6, which makes the observation *post* instead of "ante." The change of wording *ante* to *post* is made in the printed book, but not in the journal.

Now, since Hell made no attempt at a serious observation of the beginning of the eclipse, but was (it is evident) content with incidentally remarking it as he was taking time observations with his quadrant; since, also, it came within 10^s of an observation of altitude, so that he could not independently have noted it, he might well have been uncertain as to whether it was 8^s or 9^s before or 8^s or 9^s after the altitude time, and have changed his opinion after writing the note. Indeed, in the printed book he speaks of the numbers as a mere guess: "accipiebam correspondentes." Again, looking at the matter from a practical standpoint, this very alteration may supply us with a ground for believing that Hell's corrections were not made with the object of deceiving, for he could have had no such object in this alteration. He lays no stress on the observation, expressly says that such a contact cannot be accurately observed, and does not use it to determine his longitude.* Only the observed end of the eclipse he considered available for this purpose, and *he gives this without alteration.*

* Since writing this sentence, I find its last statement curiously at fault. It is true that Hell repeatedly expresses the view here attributed to him, remarking: "Et cum verus in Initio Eclipsium Solarium contactus limbi Lunæ cum limbo Solis sit observatu impossibilis . . . solo utar fine Eclipseos variis in locis observato"; and he carries through his discussion on this principle. But when he comes to the Wardhus observations, he suddenly brings in an observed time of beginning, $21^h\ 22^m\ 47^s$, and actually pretends to give it the same weight as the observation of end. Between this time and the altered record in the journal there is a break of continuity arising from the fact that neither in MS. nor print does he give the clock error he applied. But the clock error computed from his data is $45^m\ 32^s$, which would give $10^h\ 8^m\ 19^s$ as the adopted clock time, which corresponds to nothing, but is nearest to the altitude itself. It might be supposed that the estimated 5 or 6 seconds was subtracted before applying the clock error, but in one place he expressly says this is still to be done. The substance of the case is this:—The observed end he gives accurately and faithfully, and uses it correctly. The beginning he frankly acknowledges to have been nothing but a series of guesses, yet, having adjusted the guesses to give a longitude only 2^s different from that of the end, he treats it as a sound result.

We now go back to the observations of contact, beginning with first contact. In his journal he first wrote: "Venus hora 9. m. 1?′ 35″ observata est, jam parte aliqua sui diametri ingressa, ita ut existimem primum contactum 20″ circiter ante factum." The figure in the place (?) is illegible in consequence of having been blotted out with the finger before the ink got dry. There is a vague suggestion of a figure 4 in the blot, but superposed on this a much better defined loop, apparently the top of a figure 6, as Hell used to write it. But the bottom of the 6 is totally wanting, though it ought plainly to show. Then over the blotted figure is written a heavy figure 5, and over the 35 is written an equally heavy 17, thus making the time $9^h\ 15^m\ 17^s$. An attempt was also made to blot out the 2 in the 20 by a stroke of the finger before the ink got dry, but enough of the figure was left for identification. Over it is written 3, making the estimate 30^s instead of 20^s.

It is quite clear to me that the alterations were made with the same ink as the original, apart from the testimony afforded by the blots; for, although the corrections look strikingly darker than the rest of the writing, we find that wherever an unusually thick layer of ink happened to run from the pen, it looks almost as dark.

On this alteration Littrow remarks that it was probably made "nach der erst spàter, aus dem Austritte bekannt gewordenen Verweilung des Venusdurchmessers am Sonnenrande." I cannot explain this suspicion. The "Verweilung aus dem Austritte" was $18^m\ 9^s$, which, subtracted from the time of internal contact at ingress, gives $9^h\ 14^m\ 32^s$ for first external contact. This is 45^s earlier than the corrected time, and 15^s earlier after the estimated 30^s is subtracted.

For more light we refer to the printed account, which is very explicit. The three men were at the telescopes, an assistant at the clock, carefully watching the face. Whoever saw a small notch in the expected place "illico exclamaret," while "famulus" was to note hour, minute and second by the clock. Borgrewing called first, and immediately afterwards Sajnovics; then Hell, looking into his telescope, saw it. "Erat autem momentum, quo D. Borgrewing & P. Sajnovics exclamarunt, famulo indicante in horologio Viennensi $9^h\ 15'\ 17''$."

Returning to the MS., it looks to me as if a 6 was first written; before the ink was fully dry a 4 was written over it, but immediately erased with the finger and changed to a 5. However this may be, I see no more plausible explanation of the change than some accidental error in first writing down the time in the journal after the observation was over. It is not stated whether "famulus" communicated his time by speech or writing, and I cannot but suspect that the entire minutes were partly guess-work. But the coincidence of the number of seconds (35) with that given in the next following record, that of internal contact, is at least suggestive. Of course Hell had his rough

record of the contact before him when he wrote. Can it be supposed that, in the hurry of writing he took the seconds out of the wrong line, but not the minutes? If so, it would not only explain the error, but would afford positive proof that the disputed record of internal contact was before his eyes at Wardhus when he wrote.

I can only regard one conclusion as certain: that the corrections were made at the time of writing, and without the slightest intention of giving anything but the actually observed moment when *Venus* was first seen.

We now come to the much-disputed observations of internal contact, which appear in the journal in the following form:—

	h	m	s	
"Videtur contactus fieri	9	32	35	
Contactus certus visus		32	41	
fulmen		32	48	
Pater Sajnovics suo tubo contactus dubius	9	32	30	30
certissimus ut ajebat ...		32	45	45"

At first sight the figures of seconds, 35 and 41, in Hell's observations seem to be corrected figures. Littrow remarks upon them that the paper here and below bears marks of having been scraped, and that the original figures of seconds had been carefully erased; in consequence the ink had spread in the paper. But one sees at a glance that the latter statement is erroneous. The figures have not that diffused outline which arises from the absorption of ink in the tissue of the paper, but are, on the contrary, well defined with perfectly sharp edges and no loss or change of tint near the border. It is, however, true that when one looks carefully he receives the impression that the paper has been scraped all the way down the column of seconds, and especially where the observations of Sajnovics are written. But we may also note that this is near where the paper has been folded, and that there are diversities of the same sort here and there in other parts of the MS., which evidently are the mere effect of age and accident. Moreover, it is only Hell's figures of seconds which show the slightest trace of being written on a scraped surface.

Happily the question of erasure admitted of an easy and decisive settlement. The paper is of a kind which I believe is now called "wove," and of which the original ribbed surface has not been smoothed off by glazing. It was therefore examined in a dark room by direct sunlight shining through an opening, and the paper was held so that the rays should strike it at a very small angle. The ribbed texture of the surface was then brought out in bold relief of light and shadow, and it was clearly seen that the ribs extended continuously through Hell's disputed figures without the slightest break or loss of strength, except one little depression between the lines where it looked as if a

dot had been dug out with the point of a knife. Over the observations of Sajnovics the ribs are not so distinct, but they were most obliterated in the column of minutes, about which there is no dispute. Moreover, these variations are seen everywhere on the paper.

To put the matter still further beyond doubt, I asked Director Weiss's permission to write on one of the blank pages and try whether it were possible to erase the figures without injuring the texture of the surface. It was not found possible when the test of oblique sunlight was applied.

The question of erasure thus disposed of, our attention is once more directed to Hell's heavy figures, 35 and 41. We first remark that Hell's style of figure is so distinctive that in all other cases where he has written one figure over a different one, no matter how heavily, parts of the original figure can be seen protruding, and, when not blotted out with the finger, can be identified. But in this case, there is but a single trace of a figure under those written—namely, when examined with a magnifying glass, we see under one edge of the 4 what seems to be part of an original 4.

The evidence is therefore conclusive that no different figures from those now visible were ever written here. If, then, they are in any way the result of calculation from other observations, the place must have been left blank until Hell got back to Copenhagen, and made the necessary calculations. This hypothesis seems to me too fanciful for serious discussion, especially as we have an obvious explanation of the suspicious character of the figures. The ink did not always flow well from the pen, and figures as well as letters are frequently retouched in this part of the MS. Noticing that the figures as he first wrote them were not so complete and distinct as he desired them, he immediately wrote them over again in the spirit and with the hand of a man who was determined that no imperfections of pen and ink should be allowed to render so important a record doubtful.

This explanation is possibly in contradiction with a statement of Littrow that the figures 35 and 41 are made in much darker ink than that of the original. I say "possibly," because I am unable to infer from Littrow's statement exactly what individual figures and words he meant to say were written with this "viel schwarzerer Tinte." But that he was entirely at fault in saying that the corrections and alterations here described were made in different ink, my eyes do not permit me to doubt. The ink, of course, looks darker where the figures are heavily re-written, but this is only because the layer of ink is thicker. The tint is obviously the same.

We now reach a part of the record which looks more suspicious. The line "fulmen 9 32 48" is not only an interlineation, but is written in decidedly different ink from all the original MS.—an ink which has not faded so much as the other, and so has almost a blue tinge by contrast. That Littrow, in

accusing him of Hell's forgery, should have failed to dwell upon the obvious difference between this ink and that with which the alterations were made leads me to suspect a defect in his sense of colour.* The original journal, up to the time that Hell left Wardhus, being all written in one kind of ink, we conclude that the insertion was made after he reached Copenhagen. To judge of its meaning and origin we must refer to Hell's printed work, where the time is given as that of the formation of the thread of light. Moreover, this time and that of certain contact have reference to foot-notes in which it is remarked that some observers take the one, and some the other, for the true contact. I therefore conclude that he did not add this phase until he had seen the observations of others. We therefore meet the question, Was it a manufactured time, the material for which was furnished by other observations, or was it fixed solely from what he saw at Wardhus? Two circumstances seem to me to render the first hypothesis very improbable.

The first is, that the time $32^m\ 48^s$ is unaltered in the MS. and identical with that in the printed book. A time concocted from other sources would have been subject to so many alterations as new data came in, that we could not expect this coincidence.

The other is, the shortness of the interval, 7^s, between the two phases. The observations in Western Europe, which Hell must have first seen, were made with a very low altitude of the Sun, and so gave differences ranging from 10^s or 20^s up to 60^s. A difference manufactured from these data could not have been so small as 7^s.

Two hypotheses are before us as to how the insertion was determined. We may suppose that Hell, when he found he had omitted what other observers considered an important phase, tried to remember how long after the recorded contact he first saw the Sun's limb continuous, and wrote the result in his journal; or we may suppose that he made a memorandum at the time of the observation, but omitted to copy it in the journal, either through inadvertence, or because he deemed it too late for contact. When he found the phase important, he merely copied the omitted record in his journal.

The use of the queer word "fulmen," which appears only in the MS., seems to me to give colour to the last hypothesis. We can hardly conceive of one using it deliberately, after six months, to express the formation of the thread of light; whereas at the

* At the time of writing this sentence (which he has been careful not to alter) the writer had no idea that any defect was known to exist in Littrow's sense of colour. But on reviewing the comparison of his description with the MS., the case seemed even stronger than the writer had put it. He therefore made inquiries of an authority likely to be well-informed, whether Littrow had ever been suspected of colour-blindness, and was informed in reply that he really was colour-blind to red, and could see no difference between the colour of Antares or Aldebaran and that of other stars. After receiving this information no further note was made of Littrow's views of the different inks used.

moment of observation, in the excitement and hurry, it would be a very natural single word to designate the rapid increase of the effulgence of solar light around the following limb of *Venus*, which follows true contact at ingress.*

In printing, the 41^s of the MS. has, intentionally or through inadvertence, been changed to 42^s. I have no explanation of this to offer. Nor can I explain the double column of seconds in the record of Sajnovics' times.

We come now to egress. The times of Hell's notes of the "gutta nigra" are each increased by 2^s, but obviously this correction was made at the time of writing. More serious is a correction of Sajnovics' time. As originally written, they read—

"Pater Sajnovics contactus dubius	...	15 26 20	
certus	...	26"	

So far as can be inferred from the MS., the first second might have been 26 as well as 20, only then the two times would have been the same, which is improbable. The last line, "certus . . . 26," and the word "dubius," were then struck out on the spot, and the word *certus* substituted for *dubius*. Whether this was merely a suppression of the "contactus dubius," or included also a change of the "contactus certus" from 26 to 20, we cannot say, the MS. being torn where the top of the 6 belongs; but the latter seems more probable, as otherwise there would have been no object in the change. But this is not all. The 20 or 26 is again changed to 18, and so printed. Moreover, this last change appears to be made with a different ink, and, so far as can be judged from so small a surface, the same ink with which the line "fulmen" was written. The explanation is too obvious to need more than a statement. An observation of contact is not like one of a star transit, in which the observer must observe a moment which he cannot alter. It can be only an estimated mean moment for a gradually changing phenomenon extending through a number of seconds. This estimate is liable to change in the mind of the observer as he subsequently thinks over the progress of the phenomenon as he saw it. I should be inclined to accept a change of opinion thus reached, if it were not suggested by a comparison with the results of others. Now, Sajnovics was the constant companion of Hell, both on the journey and while the observations were going through the press. They, no doubt, discussed their times, and in consequence of such discussion Sajnovics concluded that his times were late.

In the exterior contacts the only correction is a change of Hell's time of "contactus dubius" from 20^s to 22^s, while "certus" remains 26^s. I attach no importance to this change, which was evidently made at the time of writing.

* I regard it as a strong confirmation of this view that Mr. Stone, without apparently having made any comparison with Hell's printed observations, reached this same conclusion as to the probable use of the word "fulmen." See *Monthly Notices* R. A. S., vol. xxix. p. 242.

To make this discussion more complete we may now consider certain collateral circumstances which have been supposed to cast suspicion upon Hell's intentions. First and most oft repeated among these is a supposed delay in making known his observations. The actual facts have already been mentioned. It may be added that, on his return to Copenhagen, Hell proceeded to prepare a complete account of his instruments, observations, and results, which included an investigation of his quadrant and clocks, a discussion of his latitude, longitude, and time, and a full statement of his observations. The whole paper, extending to 80 closely-printed pages, was written, printed and ready for distribution four months after his return to Copenhagen. Not only do I see no suspicious delay here, but it seems to me difficult to suppose that he could have had time to make so complete a reduction of the observations of others as to be able to compare them with his own.

It is true that he did not publish his observed times of contact in advance, as many others did. The reasons he is said to have assigned for this course—such as the amount of computation necessary, and the command of the King not to publish in advance of the official paper—are declared by Encke unworthy of the slightest consideration. They seem to me quite sound reasons. When the party got back to Copenhagen they had an audience of the King, and asked his consent to dedicate their observations to him. That observations made under his auspices, dedicated to him, and published by his Academy of Sciences, should first appear in official form, seems to me a very proper feeling, especially when we consider that, owing to the position of the station being unknown, publication in advance could have served no useful purpose.

Littrow also notes as suspicious circumstances certain expressions of devout sentiment which are scattered here and there in Hell's journal, and which he seems to regard as efforts to compound with his conscience for the sense of guilt with which it was oppressing him. This is possible. But it is equally possible that these expressions were the result of a generally devout state of mind not at all incompatible with moral integrity. Extraneous circumstances will decide the question. Each volume of Hell's *Ephemerides Vindobonienses*, so far as I have noticed, concludes with a similar sentiment. A curious incident mentioned by Sajnovics may be added. The extraordinary continuance of adverse weather which the ship encountered on her return voyage led Hell to investigate the morality of her navigators. Finding that they had on board certain contraband fish, he saw in this circumstance an explanation of the weather, and tried to get this part of the cargo disposed of. Failing in his effort, he left the ship in port and took another, after which there was an immediate cessation of the contrary winds.

In the preceding discussion I have made but slight allusion to the absence of many circumstances which we might expect to

accompany manufactured observations. I have, however, endeavoured to present all the positive evidence within reach so fully as to enable everyone to draw his own independent conclusions. My own conclusions are:—

First. The belief that there was any suspicious delay in the publication of Hell's observations, or anything in his course to give reasonable ground for a suspicion that he intended to tamper with his observations is a pure myth.

Secondly. Excepting the time of formation of the thread of light at ingress, excepting also a discrepancy of one second in the time of internal contact, and a change of two seconds in one of Sajnovics' times, it is proved, not only negatively and presumptively, but by positive evidence and beyond serious doubt, that all the essential numbers of observation given by Hell, whether relating to the transit, time, or longitude, are printed as concluded upon and written in his journal at Wardhus, before there was any possibility of communication with other observers.

Thirdly. The addition of the time of the formation of the thread of light was suggested by the accounts of other observers, but the time itself is Hell's own, obtained possibly from estimation and memory, but more probably from a memorandum made at the time of observation which he neglected to insert in his journal.

Fourthly. The alterations in Sajnovics' time of second internal contact were probably made because Sajnovics himself afterward concluded that his recorded time was too late; but it may be assumed that in reaching this conclusion he was influenced by Hell's observations.

A few words may be added respecting the writer's own proceedings in investigating this subject. In commencing the examination of Hell's journal he had no hope of doing more than decide whether it was or was not safe to use Hell's numbers as actual results of observations, and no thought of doubting the commonly received view of the case. A few notes respecting the different kinds of ink and writing were made as memoranda. Afterwards these notes were compared with Littrow's description of the MS., and the writer was perplexed to find himself differing entirely from the conclusions of Littrow. Not till the paper was nearly written did he make the inquiries which elicited the fact that Littrow was colour-blind. In justice to the latter a further explanation of the source of his probably incorrect judgment should be considered. Before he found the MS., suspicion had rested upon Hell's truthfulness. When he looked into the MS., and saw such extensive alterations in an ink seemingly different from that of the journal, the indictment seemed so clearly proved that his only duty was to make the facts which proved it known to the world. He thus unconsciously assumed the tone of a public prosecutor, and saw all the circumstances from an accuser's point of view.

The Nucleus of the Great Comet (b) 1882.
By A. Ainslie Common.

When this comet was first seen on the morning of Sept. 17, 1882, before perihelion, the nucleus appeared, when viewed with a 6-inch Helioscope, to be large, bright, and quite round, with a diameter of about 45″; although this is only an estimation by comparison with a spot then seen on the Sun, it is possibly not very much in error. The tail was then very bright, and had the appearance shown in the sketch No. 1, which is a copy of the sketch made at the time of the observation, Sept. 16, 23^h to 24^h. Clouds prevented the further observation of the comet, and it was not seen again until Oct. 3, and then only for a short time.

On the morning of Oct. 30 the comet came within reach of the 3-foot reflector, when the nucleus had the appearance of a line of light about 58″ in length; no particular condensation of this line was then noticed, but the morning was not very good, and the time of observation cut short by clouds. On the following morning this line of light was seen clearly divided in its length by a gap in the middle; the edges of this gap were much brighter than the other parts, and formed, as it were, two nuclei, the following one being the brightest. At 17^h 36^m (Oct. 30, 1882), the distance between the centres of these nuclei was 11″. At 17^h 41^m the position angle of the line of light forming the head of comet was 115° 5′, and its width about 10″.

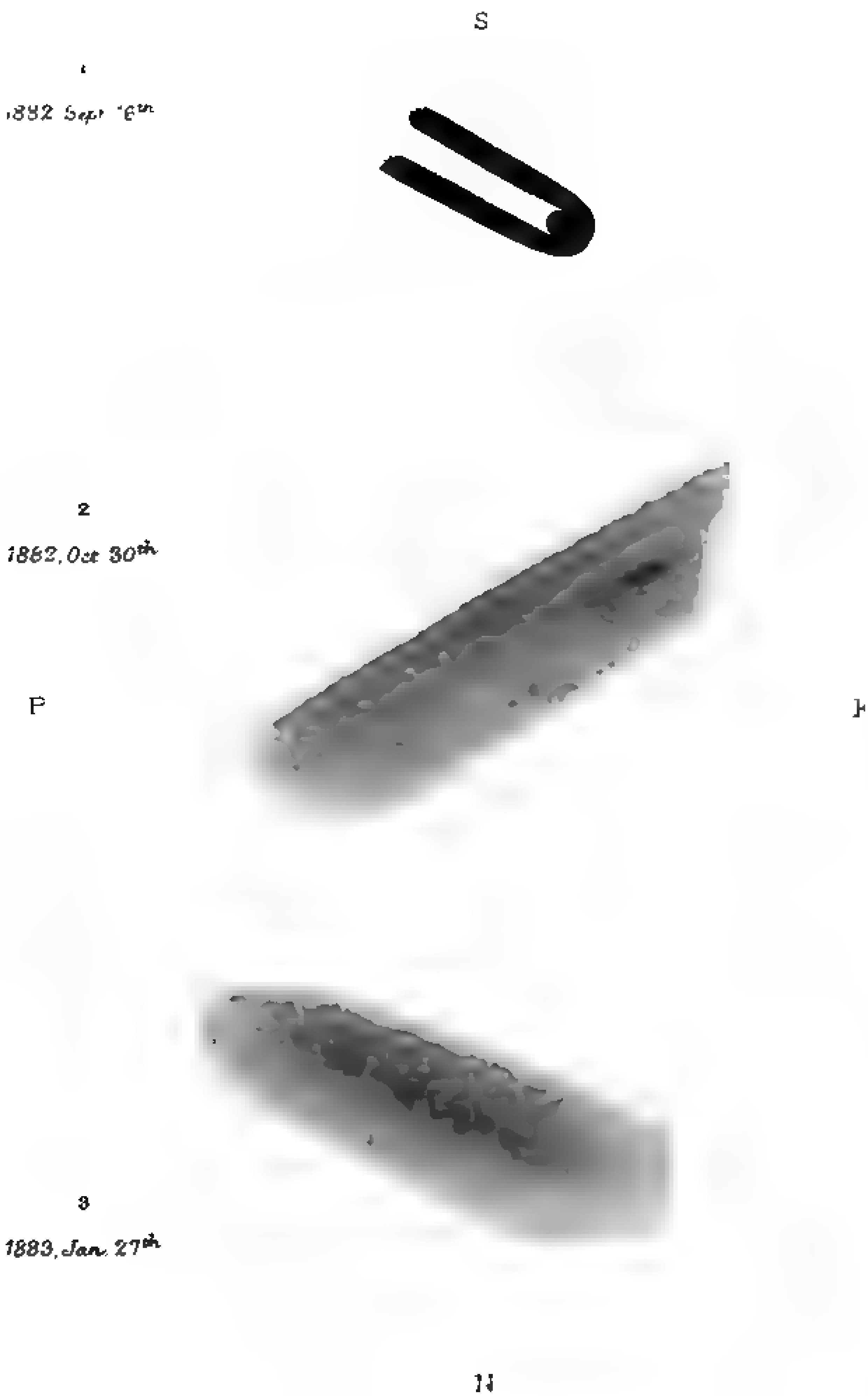
The sketch No. 2 shows the appearance on this morning.

On Nov. 1, at 17^h 2^m, the appearance of the comet was, with a low power, like the great nebula in *Andromeda*, excepting that the centre was condensed to a line of light; with higher powers, the comet appeared as seen the morning before. At 17^h 18^m, the position-angle of head was 117° 5′, and the breadth of the head or line of light 11″, the length being 100″.

On Nov. 2, at 17^h 2^m, a bending of the head was noticed concave to the north, and a slight brightening of the *following* end of the head having the appearance of another nucleus.

Subsequent observations on Nov. 5, 8, 9, 10, and 17 did not show any remarkable change, but on these days eye-observations were confined to hasty looks in the intervals of photographic experiments.

On Jan. 27, 1883, when the comet was visible in the evening, observations between 8^h 52^m and 9^h 25^m showed a remarkable change in the head of the comet; with a low power on a small telescope, and also with the 3-foot, the appearance was that of a long, brightish nebula, no tail being easily traced. With high power on the large telescope, five points of light became visible in the head, and a slight extension on the following side showing the tail. These points of light were in a straight line, and sur-



W H Wesley lith.

The great Comet (b) 1882.
A A Common

West Newman imp.

rounded with a faint haze, fading away into the sky, the south side being the brightest or most easily seen.

Taking the sketch 3, and starting from the preceding side, and calling the five points *a*, *b*, *c*, *d*, *e*, the order of brightness was: *b* and *c* equal, and equal to 11 mag. stars; *a* and *d* about one third as bright, and *e* faintest. The distance between *b* and *c* was 31″·5. The distance between *a* and *e* was 135″·5. The position-angle of the line formed by the 5 points was 240° 20′.

On Jan. 30 a short view of the comet was obtained, when the appearance was unaltered. Position-angle of *b* and *c*, 245° 5′.

On Feb. 5 the comet was well seen about 80″ north of an 11 mag. double (position 256° 50′, distance 5″). The point *c* was the brightest, otherwise the relation was the same.

The position-angle of the two points was, at $8^h\ 56^m$, 246° 15′.

On Feb. 24 the comet was well seen, $8^h\ 15^m$ to $8^h\ 35^m$. The position-angle of the two brighter points, *b* and *c*, was 256° 22′ (mean of 4 measures).

The line of points or nuclei was noticed as concave to the N.; the order of brightness was as on last observation—*c* brightest, then *b*, *d*, *a* and *e*; the distance from *b* to *c*, a mean of 3 measures, gave 33″·13.

From Jan. 27 to Feb. 24 the general appearance was much the same. On the first-named day a faint star was noticed *p.* the first nucleus in such a position that it might be taken for another nucleus symmetrically placed with regard to the others, but the motion of the comet proved it to be a star.

On Feb. 24 I strongly suspected another nucleus following the last in order, and in such a position that it would be symmetrically placed. This, however, may have been a star. The comet was bright enough to be well seen, and it is only owing to the limit of my view that further observations have not been made.

1883, *May.*

Post-Perihelion Observations of the Great Comet (*b*) 1882.
By John Tebbutt.

The only accurate observations I was enabled to obtain of the Great Comet previously to its perihelion passage are those recorded in the *Monthly Notices* for November last. I have several absolute extra-meridian determinations of position on the day before perihelion, and on subsequent days, but as these can be depended on only to the nearest minute of arc they are scarcely worth publication. Of the post-perihelion positions now sent the first four depend on the 3-inch Transit Instrument. As bright stars were observed in sunlight, when possible, in combination with the comet, the deduced Right Ascensions on the

meridian will doubtless be found to be pretty accurate. The North Polar Distances must, however, be regarded as only approximate, seeing they are derived from the readings of a setting-circle whose verniers subdivide to 20″, and by estimation to 10″. All the positions after Sept. 21 were obtained with the 4½-inch Equatorial, the filar micrometer being employed on Sept. 28, Oct. 10 and 12, and in the second set of comparisons for Oct. 7. All the other comparisons were made with an excellent square-bar micrometer. The changes which the comet's nucleus underwent after the perihelion rendered it difficult to decide as to what part of it should be observed. Towards the close of September the nucleus was large and circular, but on the 30th of that month it was first noticed to be elongated in the direction of a parallel of declination. On Oct. 2 its major axis was estimated to be three or four times its minor, and throughout the month the nucleus gradually increased in length, but not correspondingly in breadth. The inclination of the major axis to the parallel of declination gradually increased till about Nov. 22, when it was 45°; the nucleus, however, had become comparatively broader, and was very diffused and ill-defined. The second position for Oct. 7 and the positions for Oct. 10, 13, 14, and 16, refer to a small point of condensation situated about one-fourth of the major axis from the *following* or eastern extremity; all the other positions are those of the centre of the nucleus. During the latter part of October and early part of November the nucleus was more condensed at its extremities than in the middle, the *following* extremity being much the brighter. At the close of November this characteristic had disappeared. On Oct. 26 I adopted the plan of observing the contacts of each bright extremity of the nucleus with the four edges of the bar-micrometer, and thus obtained data for determining the coordinates of the centre and of the extremities. In the columns headed $\Delta\ \alpha$, $\Delta\ \pi$, I have given the corrections, always positive, to be applied to the tabulated R.A. and N.P.D. of the centre in order to obtain the corresponding coordinates of the brighter or *following* extremity. These corrections applied with the contrary sign will of course furnish the coordinates of the *preceding* extremity. During the latter half of November it was impossible to observe the ends of the nucleus with precision. The expediency of the above-described method of observation is fully illustrated by the fact that at Cordoba (see *Ast. Nach.* No. 2481) the *preceding* extremity of the nucleus was observed, though it is rather remarkable that it was recorded as the brighter.

During December and January the comet appeared as an ill-defined and somewhat oval nebulosity, slightly condensed towards the centre, but during February its oval form was not so well marked. During these months the centre only was observed. The comet is now barely visible in the telescope.

	Windsor Mean Time.	Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δπ	Parallax Factors for R.A. Log. $\frac{p}{\rho}$	Parallax Factors for N.P.D. Log. $\frac{q}{\rho}$	No. of Comp.	Comp. Star.
	d h m s	h m s		° ′ ″					
1882, Sept.	18 23 34 7	11 25 32·72		89 10 35·3			+9·7499		
	19 23 22 47	11 18 7·75		90 3 25·1			+9·7401		
	20 23 13 4	11 12 19·46		90 51 32·7			+9·7308		
	21 23 4 19	11 7 29·86		91 34 46·6			+9·7219		
	28 17 30 18	10 46 33·54		95 39 12·2		−8·7242	+9·7174	1	1
	29 17 33 51	10 44 21·04		96 10 13·5		−8·7181	+9·7121	1	2
	30 17 7 29	10 42 22·03		96 40 8·2		−8·7313	+9·7164	2	2
Oct.	2 16 58 44	* + 2 36·99		* + 12 22·0		−8·7307	+9·7110	5	3
	2 17 2 55	* + 4 58·91		* + 17 49·5		−8·7283	+9·7094	2	4
	3 17 0 51	10 36 50·67		98 7 27·1		−8·7266	+9·7057	7	5
	5 16 29 30	10 33 35·59		99 2 30·7		−8·7385	+9·7103	4	6
	5 16 29 30	10 33 34·96		99 2 29·1		−8·7385	+9·7103	4	7
	5 16 36 54	10 33 34·48		* − 2 46·6		−8·7350	+9·7070	6	8
	6 16 34 28	* − 1 2·64		* − 2 25·5		−8·7339	+9·7032	3	9
	6 16 41 56	10 32 1·84		99 29 59·7		−8·7296	+9·6997	6	10
	7 16 17 56	10 30 32·20		99 56 12·0		−8·7400	+9·7072	5	11
	7 16 56 41	10 30 30·13		99 56 56·4		−8·7159	+9·6868	11	11
	10 16 10 29	10 26 14·43		101 14 19·7		−8·7376	+9·6963	9	12
	12 15 46 42	10 23 30·34		102 4 32·0		−8·7450	+9·7007	2	13

Windsor Mean Time.	Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δπ	Parallax Factors for R.A. Log. $\frac{p}{P}$	Parallax Factors for N.P.D. Log. $\frac{q}{P}$	No. of Comp.	Comp. Star.
d h m s	h m s		° ′ ″					
1882, Oct. 13 16 44 54	10 22 7·40		102 30 28·7		−8·7016	+9·6560	2	14
14 15 57 56	10 20 49·62		102 54 25·2		−8·7355	+9·6816	7	15
16 15 46 37	* +12 18·30		* + 1 15·4		−8·7375	+9·6775	6	16
19 15 14 51	10 14 13·12		104 54 0·8		−8·7481	+9·6838	3	17
19 15 23 18	10 14 12·93		104 54 4·5		−8·7440	+9·6768	4	18
19 15 53 4	10 14 12·32		104 55 10·5		−8·7244	+9·6520	13	19
22 15 22 54	10 10 10·16		106 4 28·1		−8·7373	+9·6558	5	20
22 15 22 54	10 10 10·09		106 4 32·5		−8·7373	+9·6558	5	21
23 15 46 26	10 8 46·56		106 28 3·4		−8·7151	+9·6259	7	20
23 15 46 26	10 8 46·33		106 28 4·6		−8·7151	+9·6259	7	21
26 15 39 19	10 4 32·57	2·75	107 36 17·0	0·7	−8·7083	+9·6058	5	22
26 15 48 40	10 4 32·12		107 36 27·8		−8·6986	+9·5962	4	22
30 15 1 53	* + 2 49·97	2·34	* − 1 38·1	5·7	−8·7277	+9·6089	11	23
30 15 1 53	9 58 38·53	2·34	109 4 56·4	5·7	−8·7277	+9·6089	11	24
30 15 1 53	9 58 38·74	2·34	109 4 46·5	5·7	−8·7277	+9·6089	11	25
Nov. 3 15 51 28	9 52 11·10	3·01	110 32 29·7	7·6	−8·6397	+9·5013	3	26
6 15 8 43	9 47 5·16	2·84	111 35 35·3	14·7	−8·6833	+9·5191	7	27
6 15 8 43	9 47 5·15	2·84	111 35 30·6	14·7	−8·6833	+9·5191	7	28
6 16 1 11	9 47 0·78	2·71	111 36 14·6	9·9	−8·5901	+9·4457	6	29

Windsor Mean Time.		Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δπ	Parallax Factors for R.A. Log. p/P	Parallax Factors for N.P.D. Log. q/P	No. of Comp.	Comp. Star.
	d h m s	h m s		° ′ ″					
1882, Nov.	7 16 6 45	9 45 13·33	3·02	111 57 15·8	13·5	−8·5648	+9·4222	4	28
	7 16 6 45	9 45 13·29	3·02	111 57 10·7	13·5	−8·5648	+9·4222	4	29
	9 15 13 35	9 41 34·70	3·00	112 37 26·0	12·9	−8·6523	+9·4692	7	30
	9 15 13 35	* + 4 5·01	3·00	112 37 26·0	12·9	−8·6523	+9·4692	7	31
	9 15 13 35	9 41 35·04	3·00	112 37 26·3	12·9	−8·6523	+9·4692	7	32
	10 14 47 41	9 39 42·36	2·98	112 57 15·4	15·4	−8·6846	+9·4945	10	33
	10 15 46 17	9 39 37·01	3·09	112 58 3·5	14·9	−8·5754	+9·4016	5	33
	14 13 54 56	9 31 40·51	4·25	114 14 33·8	19·3	−8·7249	+9·5230	10	34
	14 13 54 56	9 31 40·57	4·25	114 14 56·8	19·3	−8·7249	+9·5230	10	31
	18 14 36 21	9 22 47·35	3·70	115 29 42·5	25·9	−8·6312	+9·3779	6	36
	20 15 30 53	9 17 59·60	3·31	116 5 11·8	24·9	−8·4508	+9·2251	7	37
	20 15 30 53	9 17 59·62	3·31	116 5 14·5	24·9	−8·4508	+9·2251	7	38
	20 15 30 53	9 17 59·51	3·31	116 5 14·8	24·9	−8·4508	+9·2251	7	39
	20 15 36 15	* − 5 30·25	3·27	* + 15 8·3	23·8	−8·4303	+9·2158	6	40
	22 14 30 14	9 13 12·74	3·03	116 37 55·5	35·9	−8·5944	+9·3059	10	41
	22 14 30 14	9 13 12·41	3·03	116 37 51·6	35·9	−8·5944	+9·3059	10	42
	30 15 19 40	8 51 44·31	2·69	118 34 39·1	53·8	−8·1711	+8·9793	1	43
	30 15 19 40	8 51 43·48	2·69	118 34 38·8	53·8	−8·1711	+8·9793	1	44
Dec.	1 12 48 32	8 49 8·92		118 45 17·2		−8·6850	+9·3495	5	45

Windsor Mean Time.		Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δπ	Parallax Factors for R.A. Log. $\frac{p}{P}$	Parallax Factors for N.P.D. Log. $\frac{q}{P}$	No. of Comp.	Comp. Star.
	d h m s	h m s		° ′ ″					
1882, Dec.	1 12 48 32	8 49 8·49		118 45 14·8		−8·6850	+9·3495	5	46
	1 12 48 32	8 49 8·69		118 45 13·7		−8·6850	+9·3495	5	47
	2 12 17 40	8 46 18·92		118 56 39·5		−8·7207	+9·4065	8	45
	8 11 29 2	8 28 16·81		119 53 15·4		−8·7335	+9·4063	4	48
	8 11 29 2	8 28 16·69		119 53 16·4		−8·7335	+9·4063	4	49
	12 10 41 51	8 15 43·95		120 17 24·1		−8·7560	+9·4480	10	50
	12 10 41 51	8 15 44·09		120 17 22·6		−8·7560	+9·4480	10	51
	13 10 42 47	8 12 32·35		120 21 49·2		−8·7480	+9·4254	10	51
	13 10 42 47	8 12 32·34		120 21 50·8		−8·7480	+9·4254	10	52
	14 10 6 56	8 9 24·37		120 25 1·1		−8·7750	+9·4961	8	51
	14 10 6 56	8 9 24·51		120 25 2·8		−8·7750	+9·4961	8	52
	15 10 51 49	8 6 4·97		120 28 14·0		−8·7201	+9·3604	5	50
	15 10 51 49	8 6 4·99		120 28 10·2		−8·7201	+9·3604	5	51
	15 10 51 49	8 6 4·45		120 28 10·1		−8·7201	+9·3604	5	53
	18 10 0 25	7 56 32·41		120 32 3·8		−8·7558	+9·4398	5	54
	18 10 0 25	* − 0 25·62		* + 14 13·6		−8·7558	+9·4398	5	55
	19 12 29 27	7 52 58·90		120 31 53·1		−8·3980	+8·9230	6	54
	19 12 29 27	* − 3 59·04		* + 14 3·1		−8·3980	+8·9230	6	55
	28 9 56 41	7 25 5·76		119 58 23·8		−8·6586	+9·2644	6	56
	28 9 56 41	7 25 6·21		119 58 27·2		−8·6586	+9·2644	6	57

Windsor Mean Time.	Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δπ	Parallax Factors for R.A. Log. $\frac{p}{P}$	Parallax Factors for N.P.D. Log. $\frac{q}{P}$	No. of Comp.	Comp. Star.
d h m s	h m s		° ′ ″					
1882, Dec. 29 10 39 37	7 22 0·04		119 51 19·		−8·5397	+9·1086	6	57
1883, Jan. 1 9 4 21	7 13 24·64		119 26 57·3		−8·6986	+9·3504	4	58
1 9 4 21	7 13 24·33		119 26 57·0		−8·6986	+9·3504	4	59
7 10 35 4	6 56 53·57		118 22 6·2		−8·3072	+9·0396	6	60
9 15 24 31	6 51 19·92		117 54 28·6		+8·7231	+9·4395	7	61
9 15 24 31	6 51 20·03		117 54 27·1		+8·7231	+9·4395	7	62
12 9 54 22	6 44 45·74		117 17 8·8		−8·3498	+9·1195	8	63
12 9 54 22	6 44 45·55		117 17 5·9		−8·3498	+9·1195	8	64
14 9 52 53	6 40 15·66		116 48 39·3		−8·2901	+9·1271	4	65
Feb. 6 10 10 50	6 4 16·54		110 43 58·6		+8·2620	+9·3691	4	66
6 10 10 50	6 4 16·41		110 43 54·1		+8·2620	+9·3691	4	67
7 10 10 45	6 3 19·00		110 28 10·3		+8·2888	+9·3810	10	68
7 10 10 45	6 3 19·06		110 28 22·5		+8·2888	+9·3810	10	69
12 10 39 53	5 59 7·48		109 10 2·4		+8·4987	+9·4603	12	70
12 10 39 53	5 59 6·74		109 9 55·7		+8·4987	+9·4603	12	71
26 8 33 14	5 52 20·83		105 49 51·1		+8·2060	+9·4927	4	72
26 8 33 14	5 52 20·99		105 49 52·1		+8·2060	+9·4927	4	73
26 8 33 14	5 52 20·53		105 49 52·2		+8·2060	+9·4927	4	74
26 8 33 14	5 52 20·92		105 49 46·4		+8·2060	+9·4927	4	75
Mar. 2 9 1 48	5 51 29·44		104 57 23·8		+8·4237	+9·5330	5	76

Windsor Mean Time.	Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δϖ	Parallax Factors for R.A. Log. $\frac{p}{P}$	Parallax Factors for N.P.D. Log. $\frac{q}{P}$	No. of Comp.	Comp. Star.
d h m s	h m s		° ′ ″					
1882, Oct. 13 16 44 54	10 22 7·40		102 30 28·7		−8·7016	+9·6560	2	14
14 15 57 56	10 20 49·62		102 54 25·2		−8·7355	+9·6816	7	15
16 15 46 37	* + 12 18·30		* + 1 15·4		−8·7375	+9·6775	6	16
19 15 14 51	10 14 13·12		104 54 0·8		−8·7481	+9·6838	3	17
19 15 23 18	10 14 12·93		104 54 4·5		−8·7440	+9·6768	4	18
19 15 53 4	10 14 12·32		104 55 10·5		−8·7244	+9·6520	13	19
22 15 22 54	10 10 10·16		106 4 28·1		−8·7373	+9·6558	5	20
22 15 22 54	10 10 10·09		106 4 32·5		−8·7373	+9·6558	5	21
23 15 46 26	10 8 46·56		106 28 3·4		−8·7151	+9·6259	7	20
23 15 46 26	10 8 46·33		106 28 4·6		−8·7151	+9·6259	7	21
26 15 39 19	10 4 32·57	2·75	107 36 17·0	0·7	−8·7083	+9·6058	5	22
26 15 48 40	10 4 32·12		107 36 27·8		−8·6986	+9·5962	4	22
30 15 1 53	* + 2 49·97	2·34	* − 1 38·1	5·7	−8·7277	+9·6089	11	23
30 15 1 53	9 58 38·53	2·34	109 4 56·4	5·7	−8·7277	+9·6089	11	24
30 15 1 53	9 58 38·74	2·34	109 4 46·5	5·7	−8·7277	+9·6089	11	25
Nov. 3 15 51 28	9 52 11·10	3·01	110 32 29·7	7·6	−8·6397	+9·5013	3	26
6 15 8 43	9 47 5·16	2·84	111 35 35·3	14·7	−8·6833	+9·5191	7	27
6 15 8 43	9 47 5·15	2·84	111 35 30·6	14·7	−8·6833	+9·5191	7	28
6 16 1 11	9 47 0·78	2·71	111 36 14·6	9·9	−8·5901	+9·4457	6	29

Windsor Mean Time.		Comet's Apparent R.A.	Δα	Comet's Apparent N.P.D.	Δπ	Parallax Factors for R.A. Log. $\frac{p}{P}$	Parallax Factors for N.P.D. Log. $\frac{q}{P}$	No. of Comp.	Comp. Star.
	d h m s	h m s		° ′ ″					
1882, Nov.	7 16 6 45	9 45 13·33	3·02	111 57 15·8	13·5	−8·5648	+9·4222	4	28
	7 16 6 45	9 45 13·29	3·02	111 57 10·7	13·5	−8·5648	+9·4222	4	29
	9 15 13 35	9 41 34·70	3·00	112 37 26·0	12·9	−8·6523	+9·4692	7	30
	9 15 13 35	* + 4 5·01	3·00	112 37 26·0	12·9	−8·6523	+9·4692	7	31
	9 15 13 35	9 41 35·04	3·00	112 37 26·3	12·9	−8·6523	+9·4692	7	32
	10 14 47 41	9 39 42·36	2·98	112 57 15·4	15·4	−8·6846	+9·4945	10	33
	10 15 46 17	9 39 37·01	3·09	112 58 3·5	14·9	−8·5754	+9·4016	5	33
	14 13 54 56	9 31 40·51	4·25	114 14 33·8	19·3	−8·7249	+9·5230	10	34
	14 13 54 56	9 31 40·57	4·25	114 14 56·8	19·3	−8·7249	+9·5230	10	31
	18 14 36 21	9 22 47·35	3·70	115 29 42·5	25·9	−8·6312	+9·3779	6	36
	20 15 30 53	9 17 59·60	3·31	116 5 11·8	24·9	−8·4508	+9·2251	7	37
	20 15 30 53	9 17 59·62	3·31	116 5 14·5	24·9	−8·4508	+9·2251	7	38
	20 15 30 53	9 17 59·51	3·31	116 5 14·8	24·9	−8·4508	+9·2251	7	39
	20 15 36 15	* − 5 30·25	3·27	* + 15 8·3	23·8	−8·4303	+9·2158	6	40
	22 14 30 14	9 13 12·74	3·03	116 37 55·5	35·9	−8·5944	+9·3059	10	41
	22 14 30 14	9 13 12·41	3·03	116 37 51·6	35·9	−8·5944	+9·3059	10	42
	30 15 19 40	8 51 44·31	2·69	118 34 39·1	53·8	−8·1711	+8·9793	1	43
	30 15 19 40	8 51 43·48	2·69	118 34 38·8	53·8	−8·1711	+8·9793	1	44
Dec.	1 12 48 32	8 49 8·92		118 45 17·2		−8·6850	+9·3495	5	45

Mean Places of the Comparison Stars for the Beginning of the Year of Observation, and the Reductions to the Apparent Places for the Days of Observation.

Star.	Mean R.A.	Reduction. +	Mean N.P.D.	Reduction. +	Authority.
	h m s	s	° ′ ″	″	
1	10 14 44·00	2·03	95 36 29·8	11·4	Lalande, 20075.
2	10 19 50·51	2·03 / 2·05	96 27 57·8	11·5 / 11·5	Radcliffe Obs. 1858, 688; Wash. Cat. 1860, 4336; Gr. 7 Yr. Cat. 1864, 1265; Bruxelles Cat. 1874, 762.
3	10 35 57	2·04	97 26 20	11·7	Equatorial Obs.
4	10 33 35	2·05	97 20 55	11·7	
5	10 36 32·87	2·05	98 6 32·5	11·7	Lalande, 20677.
6	10 40 16·80	2·07	99 5 34·4	11·6	„ 20757.
7	10 43 48·94	2·07	99 13 32·8	11·7	„ 20850.
8	10 33 55	2·09	99 5 10	11·5	Star 9 mag., Equatorial Obs.
9	10 33 3	2·11	99 32 7	11·4	„ „ „
10	10 28 25·94	2·12	99 17 25·5	11·3	Wash. Cat. 1860, 4401.
11	10 30 25·02	2·13	99 58 13·2	11·3	Lalande, 20521.
12	10 31 20·99	2·18	101 8 5·1	11·2	„ 20545.
13	10 4 20·80	2·29	102 13 58·6	10·2	Radcliffe Obs. 1873, 506; Bruxelles Cat. 1873, 1596 and 1597; Cape Cat. 1880, 5507.
14	10 20 4·97	2·26	102 32 8·1	10·7	Lalande, 20242.
15	10 25 12·12	2·27	102 58 59·8	10·8	„ 20389.
16	10 5 49	2·36	103 42 12	10·1	Star 8½ mag., Equatorial Obs.

Star.	Mean R.A.	Reduction. +	Mean N.P.D.	Reduction. +	Authority.
	h m s	s	° ′ ″	″	
17	10 2 53·79	2·43	105 2 3·7	9·8	Arg. Oeltzen, 10397 and 10398.
18	10 3 27·09	2·43	104 54 28·0	9·9	„ 10403 and 10404.
19	10 15 8·79	2·40	104 54 10·3	10·3	Lalande, 20089.
20	10 10 44·24	2·48	106 11 16·2	10·0	Arg. Oeltzen, 10490.
21	10 20 23·01	2·45	106 14 4·8	10·3	Nautical Almanac, 1882.
20	10 10 44·24	2·50	106 11 16·2	10·1	Arg. Oeltzen, 10490.
21	10 20 23·01	2·47	106 14 4·8	10·4	Nautical Almanac, 1882.
22	9 58 25·19	2·61	107 31 49·7	9·5	Arg. Oeltzen, 10327.
23	9 55 46	2·72	109 6 44	9·3	Star 8 mag., Equatorial Obs.
24	10 1 46·62	2·70	109 8 1·3	9·5	Arg. Oeltzen, 10381.
25	10 2 46·78	2·69	109 9 53·1	9·6	„ 10396.
26	9 52 15·56	2·83	110 37 7·7	9·1	„ 10252.
27	9 43 20·91	2·95	111 28 15·7	8·9	Lalande, 19275.
28	9 49 37·39	2·92	111 46 41·3	9·1	Arg. Oeltzen, 10212.
29	9 49 3·68	2·92	111 55 50·9	9·0	„ 10206.
28	9 49 37·39	2·96	111 46 41·3	9·2	„ 10212.
29	9 49 3·68	2·95	111 55 50·9	9·1	„ 10206.
30	9 33 42·32	3·07	112 33 46·4	8·7	„ 9965 and 9966.
31	9 37 27	3·05	112 25 39	8·8	Star 7½ mag., Equatorial Obs.
32	9 45 36·86	3·02	112 27 56·7	9·1	Arg. Oeltzen, 10163.

Star.	Mean R.A.	Reduction. +	Mean N.P.D.	Reduction. +	Authority.
	h m s	s	° ′ ″	″	
61	6 54 55·65	2·29	117 43 50·1	10·8	Wash. Cat. 1860, 2827; Cape Cat. 1880, 3341.
62	6 57 3·52	2·29	117 46 4·9	10·8	Arg. Oeltzen, 6085 and 6086; Greenw. 6 Yr. Cat. 1850, 530; Radcliffe Obs. 1858, 499; Wash. Cat. 1860, 2845; Wash. Obs. 1875, 301; Cape Cat. 1880, 3370.
63	6 40 11·74	2·26	117 13 55·0	12·0	Arg. Oeltzen, 5615 and 5616; Wash. Cat. 1860, 2729; Wash. Obs. 1873, 161, and 1874, 36; Cape Cat. 1880, 3179.
64	6 43 54·35	2·27	117 15 2·4	11·9	Arg. Oeltzen, 5718, 5719, 5720 and 5721; Wash. Cat. 1860, 2747; Cape Cat. 1880, 3216.
65	6 48 18·32	2·28	116 48 41·2	12·4	Wash. Merid. Tr. Zone, 210,9; Wash. Mur. Cir. Zone, 152,8.
66	6 4 13·04	1·97	110 39 45·3	16·9	Arg. Oeltzen, 4697.
67	6 13 59·30	2·02	110 52 42·3	17·0	Lalande, 12118; Arg. Oeltzen, 4937 (Arg. Oeltzen R.A. rejected).
68	6 4 45·43	1·96	110 28 54·2	17·0	„ 11775; Arg. Oeltzen, 4709 and 4710.
69	6 10 6·41	1·99	110 14 20·1	17·0	„ 11984.
70	6 2 36·23	1·89	109 9 11·8	17·5	Arg. Oeltzen, 4665, 4667 and 4668; Greenw. 7 Yr. Cat. 1864, 787; Bruxelles Cat. 1873, 932; Cape Cat. 1880, 2801.
71	6 3 4·55	1·89	109 24 56·4	17·5	Lalande, 11721; Arg. Oeltzen, 4679 (1′ subtracted from Arg. Oeltzen N.P.D.).
72	5 49 7·99	1·61	105 45 20·9	17·8	Arg. Oeltzen, 4416.
73	5 50 53·24	1·62	105 32 28·5	17·8	„ 4448.
74	5 54 30·17	1·64	105 48 50·6	18·0	Lalande, 11409.
75	5 56 22·99	1·65	105 35 27·6	17·9	Arg. Oeltzen, 4541 and 4542.
76	6 0 51·60	1·61	104 55 32·9	18·2	„ 4621; Greenw. Obs. 1859, 169; Cape Cat. 880, 2780.

Windsor, N. S. Wales:
1883, *March* 6.

Note on Photographs of κ Crucis, η Argus, and the Nebula in Orion, and on Longitude Determinations at Melbourne. By R. L. J. Ellery, F.R.S.

(*Extract from a letter to Mr. Stone.*)

I forward herewith photographs, obtained with the Great Telescope, of κ *Crucis*, η *Argus*, and the nebula in *Orion*, for the Royal Astronomical Society. We have lately been experimenting with emulsion plates, and these are some of our first results, which I think are promising. You will notice in κ *Crucis* the great difference in size of the image in the three coloured stars which appear nearly of the same magnitude in the telescope.

Our longitude operations Singapore, Port Darwin, and Banjoewangie, as well as Port Darwin, Adelaide, and Melbourne, are satisfactorily concluded. The mean differences (which are, however, yet subject to small corrections for relay time, &c.) are wonderfully consistent and close. You will hear more of this next mail.

Observatory, Melbourne:
1883, *March* 15.

[The photographs have been placed in the Society's library.]

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. JUNE 8, 1883. No. 8.

E. J. STONE, M.A., F.R.S., President, in the Chair.

Lieut. William Heron Coombs, R.N., Indian Marine Survey;
Thomas Kilner Mellor, 3 Belmont Street, Huddersfield;
John Pender, M.P., 18 Arlington Street, W.; and
William John Vernon Vandenberg, F.M.S., Hornsey, Middlesex;

were balloted for and duly elected Fellows of the Society.

Note on Delaunay's Expression for the Moon's Parallax. By Professor J. C. Adams, M.A., F.R.S.

The process employed in Delaunay's Theory of the Moon consists in making a great number of successive changes from one system of elements to another, these changes being so conducted that the equations which give the variations of the elements always retain their canonical form, until at length all the sensible periodic terms in the disturbing function are got rid of, and the elements are thus reduced to three constants and three angles which vary in proportion to the time.

After each such change of elements, the expressions for the three coordinates of the Moon, which are supposed to be known in terms of the old system of elements, must be transformed so as to be expressed in terms of the new.

These transformations being made independently, we may, if we choose, find some of the coordinates with a greater degree of precision than others.

Delaunay has, as is well known, followed the example of Plana in developing his coefficients in series of ascending powers of the small quantities m, e, e' and γ.

Now, two of the Moon's coordinates, viz. the longitude and latitude, can be directly compared with observation, whereas

the third coordinate, viz. the radius vector, can only be indirectly inferred from observation through the parallax, to the sine of which it is inversely proportional.

Hence the accuracy of the theoretical values of the longitude and latitude can be much more severely tested by observation than that of the radius vector.

Delaunay has, on account of this circumstance, found the analytical expressions for the longitude and latitude with a much greater degree of accuracy than that for the reciprocal of the radius vector.

In the two former coordinates he has taken into account generally the terms of the 7th order, and in cases where the convergence of the series is found to be slow, he has included terms of the 8th and 9th orders. In the reciprocal of the radius vector, however, he has confined his attention to terms of the 5th order. Consequently, while the coefficients of the inequalities in longitude and latitude as found by him are generally only a small fraction of a second in error, the inequalities in the reciprocal of the radius vector are not found with sufficient precision to give even the parallax itself with all the accuracy which is desirable.

The coefficients of the inequalities of the parallax given by me in vol. xiii. of the *Monthly Notices*, p. 263, are considerably more accurate than those of Delaunay.

In the paper just referred to, I have given the coefficients to hundredths of a second only, and, as I have there stated, terms with coefficients less than 0″·05 have been omitted except when they can be included in the same table with larger terms.

It may be worth while to give here a more complete view of the values of the coefficients of parallax which I obtained in 1853. These results are exhibited to thousandths of a second, as the calculation gave them, although the figures in the last place of decimals are not to be depended upon.

I add, for the sake of comparison, Delaunay's coefficients of the corresponding terms as given in the *Connaissance des Temps* for 1869, and also the coefficients of Hansen's theory as transformed by Professor Newcomb. The several arguments are expressed in Delaunay's notation.

Table of Comparative Values of the Coefficients of $\dfrac{\textit{sin. Parallax}}{\textit{sin. } 1''}$.

Arg.	Delaunay.	Adams.	Hansen transformed by Newcomb.
	″	″	″
0	3422·7	3422·324	3422·09
l'	−0·4273	−0·400	−0·393
l	+186·5870	186·513	186·483
$2l$	10·1984	10·170	10·161
$3l$	0·6314	0·628	0·620

Adams.	Hansen transformed by Newcomb.
″ ·041	″ ·040
1·157	1·144
−0·948	−0·961
0·123	0·149
−0·100	−0·122
−0·710	−0·709
28·232	28·225
1·915	1·920
−0·306	−0·301
0·089	0·092
3·090	3·084
0·222	0·229
−0·047	−0·049
34·304	34·309
1·449	1·447
0·050	0·049
−0·231	−0·227
0·281	0·283
−0·307	−0·302
−0·116	−0·121
−0·106	−0·105
−0·048	−0·048
−0·086	−0·083
0·260	0·261
0·600	0·599
0·372	0·372
0·063	0·069
−0·949	−0·953
0·145	0·146
−0·106	−0·106
0·005	0·003
−0·036	−0·037
0·002	
0·014	+0·011
−0·015	−0·019
0·032	0·043
0·030	0·032
0·034	0·035

In the above many very small coefficients have been omitted.

As stated in my paper in the appendix to the *Nautical Almanac* for 1856, or in the *Monthly Notices*, vol. xiii. p. 177, my coefficients of parallax were obtained by comparing the results of the theories of Damoiseau, Plana, and Pontécoulant, and tracing out the origin of the discordances in the cases where those results did not agree with each other. These coefficients were also compared with those which I obtained by a transformation of Hansen's preliminary results as given in a paper in vol. xvii. of the *Astronomische Nachrichten*.

In Pontécoulant's method the expression for the reciprocal of the radius vector is first found, and then the expression for the longitude is derived from it. Hence the analytical values of the coefficients of parallax, given by Pontécoulant, vol. iv. pp. 149–152, 281, 282, 336, 337, are at least as accurate as the values of his coefficients of longitude.

In his final expression, however, in pp. 568–572, in which the several terms of the reciprocal of the radius vector are collected together, he neglects all terms of orders higher than the 5th, and the same omission takes place in the conversion of his coefficients of parallax into numbers.

Accordingly these numerical values, which are calculated in pp. 599–601, and collected together in p. 635, nearly coincide with the values of Delaunay, but are on the whole still less accurate.

It is greatly to be desired that some intrepid and competent calculator would undertake to make the numerous substitutions which would be required in order to find, by Delaunay's method, the expression for the reciprocal of the radius vector to the same order of accuracy as that which Delaunay has already attained in the case of the corresponding expressions for the longitude and latitude. The work would be one of simple substitution, not requiring the solution of any new equations, and consequently its only difficulty would consist in its great length.

The fact that Delaunay's determination of the value of the reciprocal of the radius vector is a comparatively rough one, affords a ready explanation of a difficulty which Sir George Airy has recently met with in his Numerical Lunar Theory.

The first operation required in this method is the substitution in the differential equations of motion of the numerical values of the Moon's coordinates as obtained in Delaunay's theory. If the theory were exact, the result of the substitution in each equation would be identically zero, so that the coefficient of each separate term in the result of the substitution would vanish. In consequence of errors in the coefficients obtained by Delaunay, however, this mutual destruction of terms will not take place, and the result of the substitution will consist of a number of terms the coefficients of which will depend on the errors of the assumed coefficients.

If, as is actually the case, these latter errors be so small that

their squares and products may be neglected, each of the residual coefficients may be represented by a linear function of the errors of the assumed coefficients, and the formation of the corresponding linear equations constitutes the second operation in Sir George Airy's method. The solution of these linear equations by successive approximations will finally give the corrections which must be applied to Delaunay's coefficients in order to satisfy the differential equations.

Now, since the proportionate errors of Delaunay's coefficients of parallax are considerable, and much greater than the errors affecting his coefficients of longitude and latitude, it will be readily understood that the result of the substitutions will be to leave considerable residual coefficients in the two equations which relate to motion parallel to the ecliptic, and much smaller residual coefficients in the third equation which relates to motion normal to the ecliptic, since in this last equation every error in the coefficients of the radius vector or of its reciprocal will be multiplied by the sine of the inclination of the Moon's orbit. This result, which might thus have been anticipated, is exactly what Sir George Airy has found to take place, according to a memorandum which he has recently addressed to the Board of Visitors of the Royal Observatory.

Since the errors affecting Delaunay's coefficients of parallax are comparatively large, it will be necessary to determine the factors by which these errors are multiplied in the equations of condition with a much greater degree of accuracy than is required in the case of the factors by which the errors of the coefficients of longitude and latitude are multiplied in the same equations. Otherwise, it will not be possible to deduce these last-mentioned errors from the equations with the requisite degree of precision. It will be necessary to take special precautions in order to determine with accuracy the corrections of the assumed coefficients in the inequalities of longitude which have long periods.

On the Change in the Adopted Length of the "Tabular Mean Solar Day," which takes place with every Change in the Adopted Value of the Sun's Mean Sidereal Motion. By E. J. Stone, M.A., F.R.S.

The view which I have taken that the so-called "mean solar day" of any of our tables is not necessarily the true "mean solar day," and that the "mean solar day" in use before 1864, for the calculation of our *Nautical Almanac*, is most certainly not the same interval of absolute time as that now adopted, and called a "mean solar day," is without doubt a startling assertion, and one likely to be sharply criticised; but I did not make it without a most careful consideration of the subject, and I feel perfectly certain of its truth. After all, the statement is not more startling than the facts for which it accounts. The meri-

dians of all our observations have either run away from the Sun and Moon in the last nineteen years by about 27^s, or astronomers have made a mistake in their count, as I have indicated, to this amount. Neither of these alternatives may appear probable, but the observations show that one of the alternatives must be accepted.

I consider that I have *mathematically* demonstrated my point, but my attention has been called to a letter by Sir G. B. Airy, in the *Observatory* magazine for May, in which that distinguished astronomer expresses, in very polite, but clear terms, his dissent from my views. The subject which I have opened out is of such importance, and the consequences which have already resulted from the changes made in 1864 are so serious in character, that I think it my duty to point out in the clearest possible manner the nature of the mistake made, and the fallacy of the reasoning by which Sir G. B. Airy has supported his dissent from my views.

In all scientific discussions the great difficulty is to fix the exact point at which our views diverge. When this can be done, the settlement of a mere mathematical question like the present should be comparatively easy. I feel, therefore, deeply indebted to Sir G. B. Airy for a clear statement of the evidence which he considers conclusive against the correctness of my views, and I shall be careful not to understate the force of the objections urged. I believe that the difficulty thus presented is the one which has chiefly influenced opinion against my views.

Sir G. B. Airy states that our observed Right Ascensions are referred to the adopted tabular places of our clock stars, and that no important changes in the tabular places of the clock stars were made with the change from Bessel's to Le Verrier's expressions for the sidereal time at mean noon in the *Nautical Almanac* of 1864. He points out that we determine the mean time corresponding to an observed Right Ascension of the Moon on the meridian from the formula that it is the equivalent in mean solar time of the sidereal interval (Observed R.A. – Tabular sidereal time at mean noon), and if we take from one of the Greenwich volumes an observed R.A. of the Moon—for instance, March 22, 1880, R.A. of centre = $9^h\ 10^m\ 59^s{\cdot}02$—and compute from this expression the Greenwich mean time, first with Bessel's value of the sidereal time at mean noon, and second with Le Verrier's value of the sidereal time at mean noon, the results will differ slightly, but by only the $\frac{1}{366}$ of the difference indicated by me. If, therefore, we compute from Hansen's tables the position of the Moon for these two separate times, the tabular R.A. will only differ by the $\frac{1}{366}$ part of the quantity indicated by me, and it is therefore quite impossible that the great errors at present existing between Hansen's tables and observations can be due to the use of the two different expressions for the tabular sidereal time. Now, I admit all the statements of fact made by Sir G. B. Airy, but I deny his conclusions. The method adopted for the computation

of Greenwich mean time is defective, and our count is wrong because our unit of time has been changed.

In questions of time there are two things to be taken into consideration—the count t, and the absolute length of the unit T, in terms of which the count is kept. If t_1 is the count with unit T_1, and t_2 the count for the same interval of absolute time with unit T_2, then we have

$$T_1t_1 = T_2t_2.$$

I have proved that the change from n' to $n' + \delta n'$ for the adopted value of the Sun's mean motion in the units of time T_1 and T_2 has established the relationship

$$T_2 = T_1\left(1 + \frac{\delta n'}{n'}\right).$$

It follows therefore, that if the count, as now conducted, differs only slightly from that formerly adopted, or $t_2 = t_1$, the error made by this false reckoning is

$$T_2t_2 - T_2t_1 = -\text{time} \times \frac{\delta n'}{n'}.$$

This indicates that the error in our present reckoning in time is increasing at about the rate of $1^s{\cdot}46$ per annum. This correction, when introduced into our theories, accounts for the large discordances shown between theory and observation in the case of the Moon and also the Sun. But, of course, if Sir G. B. Airy's count is right, or t_1 *does* equal t_2 sensibly, then T_2 and T_1 cannot differ in the way indicated by me, and there must be *some* flaw in the reasoning, or some false assumption, in what I have given as a mathematical proof of the relationship

$$T_2 = T_1\left(1 + \frac{\delta n'}{n'}\right).$$

I have stated the case against my views as strongly and clearly as possible.

It might be sufficient for me to ask those who refuse to accept my explanation of the cause of the existing errors in our theories, *which are proved to exist by our observations*, to distinctly point out my errors of assumption or of reasoning. But I am prepared to take the more direct course of showing that the present count is erroneous, and that when rightly conducted t_2 is not sensibly equal to t_1.

The so-called mean time, which is directly computed from observation, is nothing more than the equivalent in mean solar time of the sidereal interval. Observed R.A. on meridian — tabular R.A. of meridian at mean noon, and it is the error made in computing this small interval on any particular day which Sir G. B. Airy considers the total error in count arising from the change from Bessel's to Le Verrier's expressions for the tabular R.A. of the meridian, and this interval, added to the count for "days"—

and here comes in the question of what "days" if the unit has been changed—is considered the Greenwich mean time deduced from observation. But an inspection of the form Observed R.A. on meridian—Tabular R.A. of meridian at mean noon, shows that the mean noon, in this way of calculating mean time, is the instant when Observed R.A. on meridian = Tabular R.A. of meridian at mean noon; and if we adopt two different expressions for Tabular R.A. of meridian at mean noon, we must have two distinct noons. The mean noon, according to Bessel's expression, comes earlier than the mean noon according to Le Verrier's expression on any particular day by the exact interval which Sir G. B. Airy supposes to be the total error which arises from the change from Bessel's expression to Le Verrier's; the accumulative effects of this error day by day in separating the tabular position of the meridian from the true position, are entirely neglected; and it is the neglect of this accumulation of errors in the count which has made Sir G. B. Airy's count wrong. Sir G. B. Airy has obtained nearly the same count in both cases because he has taken the count of so-called days in each case from the motion of the observed meridian with respect to the stars without considering that if the increase of R.A. in Bessel's day was 360°, it will no longer be 360° when a day of Le Verrier's scale is used, but a larger quantity than 360° in the proportion of

$$1+\frac{\delta n'}{n'} : 1.$$

The following is a direct mathematical proof of the error made, but to avoid complexity I shall, at first, neglect any differences in the small terms multiplied by t^2. The method of treatment, however, is perfectly general.

Let

$$S = C + (n + a \cos \omega_0 - u)t + \lambda t^2,$$

and

$$L = C + (n' + p)t + st^2$$

be the true tabular sidereal times for the meridian of Paris and the mean longitude of the Sun when 365·25 × (the true physical mean solar day) is adopted as the unit of time. Then

$$n + a \cos \omega_0 - u - n' - p = 365{\cdot}25 \times 2\pi,$$

$$\therefore (1 + x)(n + a \cos \omega_0 - u - n' - p) = 365{\cdot}25 \times 2\pi(1 + x).$$

Let

$$(1 + x)n = N\,;\ (1 + x)a = A\,;\ (1 + x)n' = N', \text{ etc., etc.}$$

$$\therefore\ N + A \cos \omega_0 - U - N' - P = 365{\cdot}25 \times 2\pi(1 + x).$$

Then

$$S = C + (N + A \cos \omega_0 - U)\frac{t}{1+x} + \lambda(1 + x)^2.\left(\frac{t}{1+x}\right)^2$$

$$L = C + (N' + P).\frac{t}{1+x} + s(1 + x)^2.\left(\frac{t}{1+x}\right)^2.$$

Let

$$t' = \frac{t}{1+x}.$$

$$S = C + (N + A\cos\omega_0 - U)t' + \lambda(1+x)^2.(t')^2$$

$$L = C + (N' + P)t' + s(1+x)^2.(t')^2$$

$$\therefore\ S - L = 365{\cdot}25 \times 2\pi(1+x)t' + (\lambda - s)(1+x)^2.(t')^2$$

$$\therefore\ S = C + (N' + P)t' + 365{\cdot}25 \times 2\pi(1+x)t' + \lambda(1+x)^2.(t')^2$$

Consequently, therefore, the sidereal time of the meridian can never assume the form

$$S = C + At + 365{\cdot}25 \times 2\pi\,.\,t + \lambda t^2,$$

unless the physical day is known and the true values of n' and p also known.

But let

$$S' = C + (n' + \delta n' + p)t + 365{\cdot}25 \times 2\pi t + \lambda t^2$$

be the expression adopted by Le Verrier and now used in the *Nautical Almanac*, and suppose Bessel's value to have been the true value, I am really only concerned here with the change.

Then let

$$N' + P = n' + \delta n' + p,$$

which requires

$$(1+x)(n'+p) = n' + p + \delta n'$$

$$\text{or } x = \frac{\delta n'}{n'+p}.$$

Then

$$\text{true } S = C + (n' + \delta n' + p)\,.\,t' + 365{\cdot}25 \times 2\pi\left(1 + \frac{\delta n'}{n'+p}\right)t' + \lambda t_{\prime}^{2},$$

$$\text{tabular } S' = C + (n' + \delta n' + p)t + 365{\cdot}25 \times 2\pi t + \lambda t^2.$$

It is absolutely necessary for the *true* computation of mean time by the formula adopted that the theoretical expression for the R.A. of the meridian should be identical with the true expression.

A comparison of these expressions shows that in order to make S′ agree with S we must take

$$t = t' = \text{true } \frac{t}{1 + \dfrac{\delta n'}{n'+p}}$$

and introduce a term

$$365{\cdot}25 \times 2\pi\frac{\delta n'}{n'+p}.t'.$$

This term does not vanish at tabular mean noon, and *it is the neglect of this term* which makes Sir G. B. Airy's count wrong. This is a strict mathematical proof, which, without directly

assuming the change of unit, proves that it must practically have taken place with the adoption of the change from n' to $n' + \delta n'$ for the Sun's mean motion.

The error made has been that n' has been changed into $n' + \delta n'$ without recognising the necessity of the change of units, and the neglect therefore of the correction $365\cdot25 \times 2\pi \dfrac{\delta n'}{n'+p} . t$ to the tabular R.A. of mean noon when derived from Le Verrier's tables.

If we neglect this term we preserve nearly the same count, because that depends chiefly upon the term $2\pi . t$, which is assumed the same in both Bessel and Le Verrier. The neglect of this quantity by preserving our count without preserving the same unit of time necessarily makes the absolute times all wrong. The error has been that the change of unit has not been recognised. No correction for the term $365\cdot25 \; 2\pi \dfrac{\delta n'}{n'}$ has therefore been introduced into our count.

The following is the more general investigation. Since

$$(n + a \cos \omega_0 - u - n' - p) = 365\cdot25 \times 2\pi$$

we have

$$(1 + x + y\tau)(n + a \cos \omega_0 - u - n' - p) = 365\cdot25 \times 2\pi(1 + x + y\tau).$$

Let

$$n(1 + x + y\tau) = \text{N} ; \; a(1 + x + y\tau) = \text{A}; \; u(1 + x + y\tau) = \text{U} ;$$

$$n'(1 + x + y\tau) = \text{N}'; \; p(1 + x + y\tau) = \text{P}$$

$$\text{N} + \text{A} \cos \omega_0 - \text{U} - \text{N}' - \text{P} = 365\cdot25 \times 2\pi(1 + x + y\tau),$$

since

$$\text{S} = \text{C} + (n + a \cos \omega_0 - u) . t + \lambda t^2,$$

$$\text{L} = \text{C} + (n' + p)t + st^2$$

$$\text{S} = \text{C} + (\text{N} + \text{A} \cos \omega_0 - \text{U}) \frac{t}{1 + x + y\tau} + \lambda(1 + x + y\tau)^2 \left(\frac{t}{1 + x + y\tau}\right)^2$$

$$\text{L} = \text{C} + (\text{N}' + \text{P}) \frac{t}{1 + x + y\tau} + s(1 + x + y\tau)^2 \left(\frac{t}{1 + x + y\tau}\right)^2.$$

Let

$$t = \tau(1 + x + y\tau).$$

Then

$$\text{S} = \text{C} + (\text{N} + \text{A} \cos \omega_0 - \text{U})\tau + \lambda(1 + x + y\tau)^2 . \tau^2$$

$$\text{L} = \text{C} + (\text{N}' + \text{P})\tau + s(1 + x + y\tau)^2 . \tau^2 ;$$

$$\therefore \; \text{S} = \text{C} + (\text{N}' + \text{P})\tau + 365\cdot25 \times 2\pi\tau(1 + x + y\tau) + \lambda(1 + x + y\tau)^2 . \tau^2.$$

Now consider a tabular expression

$$\text{S}' = \text{C} + (n' + \delta n' + p)t + 365\cdot25 \times 2\pi . t + (\lambda + \delta\lambda)t^2.$$

Let

$$(N'+P)+\lambda\tau = n'+\delta n'+p+(\lambda+\delta\lambda)\tau$$

be made an identity by a proper determination of x and y; then since

$$N'+P=(n'+p)\,(1+x+y\tau),$$

we have

$$x=\frac{\delta n'}{n'+p} \quad \text{and} \quad y=\frac{\delta\lambda}{n'+p};$$

$$\therefore\; S=C+(n'+\delta n'+p)\tau+365\cdot25\times 2\pi\tau\left(1+\frac{\delta n'.\tau+\delta\lambda.\tau^2}{n'+p}\right)+(\lambda+\delta\lambda)\tau^2.$$

Comparing this with the tabular expression

$$S'=C+(n'+\delta n'+p)t+365\cdot25\times 2\pi\,.\,t+(\lambda+\delta\lambda)t^2,$$

we see at once that S′ can be made identical with S only by the following assumptions:—

(1) The tabular t is really τ.

(2) That we apply a correction

$$=365\cdot25\times 2\pi\left(\frac{\delta n'.\tau+\delta\lambda.\tau^2}{n'+p}\right).$$

The conclusions to be drawn are the same as before. The tabular sidereal times at mean noon require the correction

$$365\cdot25\times 2\pi\left(\frac{\delta n'.\tau+\delta\lambda.\tau^2}{n'+p}\right)$$

where τ may be taken as sensibly equal to t. This demonstration proves the necessity for a correction which if neglected would produce an apparent secular acceleration of 4″ in the Moon's mean motion.

The *rationale* of this method is simply that with every change in the unit of time we must, if we determine our count of days directly from the increase of Observed R.A. by 360°, introduce a correction to render this assumption true. If this is not done, we must of necessity make our theoretical Right Ascensions run away from our observed ones. There is no escape from such a false assumption.

Note on Mr. Stone's Paper in the last number of the "Monthly Notices."

The statement on page 343, line 8, and three following lines, is badly expressed. It should read: "From which it follows that the absolute time in an interval of t years expressed in terms of the unit t_1 exceeds the absolute time in an interval of t years expressed in terms of t_2 by

$$\frac{\delta n'}{n'}\,.\,t."$$

Preliminary Account of a Telegraphic Determination of the Longitude of the Royal Observatory, Cape of Good Hope. By David Gill, LL.D., F.R.S., H.M. Astronomer at the Cape of Good Hope.

The longitude of the Royal Observatory, Cape of Good Hope, is the origin of longitudes for the British and American Transit of *Venus* Stations in South Africa and Madagascar. I have therefore thought it desirable to publish, as soon as possible, a brief account of the recent operations connecting the longitudes of Aden and the Cape, and to quote the approximate results obtained, in anticipation of the definitive results and more detailed account that will afterwards appear in the publications of the Observatory.

On Oct. 6, 1879, I addressed Sir George Airy, then Astronomer Royal, drawing his attention to the fact that about the end of the year the Cape would probably be in telegraphic communication with England, and asking whether advantage should not be taken of this circumstance to determine the longitude of the Cape of Good Hope as soon as possible. On Nov. 13 of the same year Sir George replied, "To mention the galvanic determination of the Cape of Good Hope Observatory is quite enough; the thing must be done as soon as may be."

After much correspondence and inquiry as to possibilities, I officially addressed the Secretary of the Admiralty on 1880, June 23, enclosing a general plan of the proposed operations, together with the necessary estimates of cost.

On 1880, Sept. 20, I took advantage of the kind invitation of Commodore (now Admiral) Sir F. Richards, K.C.B., to accompany him, as his guest, on board H.M.S. "Boadicea" to Port Elizabeth and Durban, partly to select sites of observation, but especially to ascertain whether signals could be exchanged directly between Aden and Durban without the intervention of an observer at Zanzibar. At Durban I made the necessary experiments, and found that signals sent from Aden, though quite useless for longitude purposes when received on the ordinary speaking galvanometers, were quite sharp and well marked when received on Thomson's air dead-beat* galvanometer. This fact I reported to the Admiralty by telegraph from Durban, and, on my return to the Cape, received official authority to proceed with the work. The necessary huts were soon made in Cape Town, but some unforeseen delays occurred in the despatch of the transit instruments and clocks from England, and it was not until 1881, March 2, that they reached the Cape.

* In the ordinary submarine galvanometer the mirror is suspended in water; in the air dead-beat the mirror is suspended in air. The mirror in the latter is nearly of the diameter of the cylinder in which it is hung, and the length of this cylinder is limited by glass plates. The mirror moves very freely at the first impulse, but the extension of the swing is checked by the passage of air round the edge of the mirror.

One of the transit instruments and a clock were mounted in a hut in the Observatory grounds without delay, and personal equation determinations were obtained on five nights. I was about to sail for Durban on March 18 when news was received of a breakdown of the land-lines from floods on the Transkei; difficulties also were presented by the discontinuation of the Mail Steamer Service between Durban and Delagoa Bay. I therefore postponed the commencement of actual operations for three months, and afterwards changed the original programme, relegating to Mr. Finlay, my chief assistant, the part of principal travelling observer; I had every confidence in his energy and skill, and my confidence has been amply justified by results. This modification of the original plan gave me more satisfactory control over the operation as a whole, and it enabled me at the same time to commence a series of heliometer researches on stellar parallax which must otherwise have been delayed for a year.

My general plan of operations was as follows:—The travelling observers were Mr. W. H. Finlay (F.), who successively occupied Durban, Aden, and the Cape; Mr. G. W. H. Maclear (M.), who observed first at the Cape, and afterwards at Durban; and Messrs. R. T. Pett (P.) and Isaac Freeman (I.), who remained at the Cape.

At the Cape (Observatory grounds), Durban, and Aden, there were erected three similar wooden huts, each containing a powerful portable transit instrument (3 inches aperture), a clock by Dent, and the necessary apparatus for sending and receiving signals.

The clock at Durban (the middle station) was regulated to mean time, the clocks at Aden and the Cape were regulated to sidereal time. At the Cape F. and M. observed exclusively with the 3-inch transit, P. and I. with the Transit Circle. The Observatory hut-clock and Observatory transit-clock were compared by coincident beats (through the intervention of mean time chronometers) by the observers before and after each time-determination.

Since Mr. Finlay observed both at Aden and the Cape, whilst Mr. Maclear remained at Durban, the sum of the longitudes Aden-Durban, and Durban-Cape Town, would be free from personal equation *if the personal equation of Finlay and Maclear remained constant during the operation, and if the personal equation of both observers was the same for land-line and for cable signals.*

But it would have been very unsafe to make any such assumption, for the operation was necessarily a very protracted one, the observers had long sea voyages intervening between the personal equation determinations and the actual observations, as well as great changes of climate and (as it proved) of bodily health. In fact, in such operations, the accidental error is a very small matter in comparison with the *possibility* of large systematic error due to change in the personal equation of the observers.

It was therefore essential to have some control on the constancy of the habit of observation of each of the travelling observers, and this I obtained by comparing the personal equation of F. and M. with that of $\frac{\text{P.}+\text{I.}}{2}$ both before and after the expedition.

That $\frac{\text{P.}+\text{I.}}{2}$ may be accepted as a tolerably uniform standard there was good *à priori* reason to believe. Both gentlemen were experienced observers, and had observed steadily and exclusively with the same instrument for the past eight years and twenty years respectively.

The following are the results of the different series of observations that have been made, under my direction, to determine their relative personal equation.

	No. of Stars.	P.—I.
		s
In 1879, Stars N.P.D. 75° to 105°	160	+0·178
„ 105 to 120	206	+0·229
Mean		+0·204

		Probable Error.
		s
1881, Apr. 9–June 27, Longitude Time Stars	10 nights	+0·229 ± ·009
Aug. 18–Sept. 19, „	7 „	+0·207 ± ·009
Dec. 23–1882, Feb. 17 „	8 „	+0·233 ± ·021

The remarkable constancy of these relative results may be accepted as proof of the probable constancy of the absolute personal equation of both observers.

From a discussion of the numerous observations for personal equation made before and after the expedition the following are the results obtained:

Before the Expedition.		After the Expedition.	
F.	+0·150	F.	+0·110
M.	+0·007	M.	+0·047
P.	+0·032	P.	+0·034
I.	−0·189	I.	−0·191
$\frac{\text{P.}+\text{I.}}{2}$	−0·079	$\frac{\text{P.}+\text{I.}}{2}$	−0·079

where F. + M. + P. + I. = 0.

The personal equation of each observer both in sending and receiving land-line signals was also determined, by numerous trials, before and after the operation; these personalities resulted in quantities not exceeding $0^{s}{\cdot}01$, and are for the present neglected. The details will be given with a complete account of the operation.

To compare the personal equations of F. and M. in observing galvanometer signals, I arranged the following plan, which was

well carried out. I instructed F. to leave his clock at Aden, and to train a member of the telegraph staff there in the art of sending time signals. This duty was cordially undertaken by Mr. A. W. Prosser, of the telegraph staff there, and he acquired great skill in sending signals with uniformity and precision.

F. brought with him the Thomson dead-beat galvanometer which he had used at Aden, and mounted it in the hut at Durban, where the galvanometer used by M. was also mounted. Both galvanometers were then put in the Aden circuit, and signals sent by Mr. Prosser at Aden were observed by F. and M. at Durban, *each observer using his own galvanometer, but recording the same signal at the same place by the beats of the same clock.*

Any difference in the recorded times was therefore due either to personal equation or to a different degree of sensibility in the two galvanometers.

For longitude purposes it was not necessary to separate the observer's personality from the difference of the instruments, and therefore no observations were made with an exchange of galvanometers.

The following are the results of these experiments:—

Mean of 95 coincidences observed on 10 different days show that Finlay observed earlier than Maclear by $0^s\cdot261$.

And 1,820 differences (not coincidences) gave $0^s\cdot263$.

The experiments were made with the galvanometer of F. alternately first and last on the line.

If we separate these cases we have

Finlay's galvanometer first on line,	47 coincidences	$= 0^s\cdot267 \pm {}^s\cdot017$
Maclear's „	„	$= 0\cdot255 \pm \cdot016$
		Mean $0\cdot261$

That is, the clock times of submarine signals observed by Maclear with the Durban galvanometer require the correction $-0^s\cdot261$ to reduce to Finlay's habit of observation with the galvanometers employed by him at Aden.

There is still a final correction for personal equation of some importance; it is as follows:—

All the time-stars were purposely selected between Declination $+12°$ and $-29°$, so as to lie between the zeniths of Aden and Durban. At the Cape, where the determinations of personal equation were made, the time-stars all move from right to left (i.e. from left to right in the field of the transit), but at Aden they move from left to right (i.e. from right to left in the field of the transit).

In 1879, in the course of some special investigations on personal equation, I found, for all the Observatory assistants without exception, that the personal equation, in observing a zenith star, systematically differs according as the feet of the observer

are towards the north or the south* (i.e. according as the star appears to cross the field from right to left or from left to right).

By placing a reversing prism between the eye-piece and the observer's eye, it is possible to make any star appear to move from right to left or from left to right at pleasure. In this way Mr. Finlay's difference of personal equation for stars (really) moving from right to left from stars (really) moving from left to right was

Before the Longitude Expedition from	31 stars	$+0^{s}.06 \pm 0^{s}.012$
After " "	21 "	$+0.08 \pm 0.010$

Mr. Finlay's observations at Aden therefore require the correction $+0^{s}.07$ applied to his determination of "clock slow" to reduce to his habit of observation in the southern stations.

For the time determinations a list of 389 time-stars was prepared. These stars were all situated between Declination $+12°$ and $-29°$ for reasons above explained, and all, as far as possible, of 6th magnitude. From this list the observer can find a time-star for every three or four minutes of R.A., so that no opportunity for observing between clouds need be lost. A further list of 87 circumpolar southern stars were supplied to each observer. The places of all these time and polar stars have been determined with the Transit Circle (generally with a minimum of 6 observations each). The circumpolar list was printed and circulated for the benefit of Transit of *Venus* expeditions to the southern hemisphere. A time determination was defined as follows:—

1. Collimation by reversal on a collimator.
2. Level; 4 reversals.
3. Observe 4 time-stars; one pole star above, and one below, pole.
4. Level; 2 reversals.
5. Reverse Transit instrument.
6. Level; 2 reversals.
7. Observe 4 time-stars; one pole star above, and one below, pole.
8. Level; 2 reversals.

A complete determination of longitude was supposed to consist of such a time determination both before and after the exchange of signals at both ends, but it was found necessary to relax this condition because of the interruptions of cloudy

* These results were F. +·079
M. +·122
P. +·015
I. +·066

weather, which would have unduly prolonged the operation if this condition had invariably been insisted upon.

I have therefore accepted all the results in which there is a complete time determination at both ends within two or three hours of the exchange of signals; but no time determinations are accepted in which stars have not been observed in both positions of the transit.

The values of the levels were determined before and after the expedition.

All the observations have been made by *eye and ear* not only in the time determinations, but in sending and receiving signals. All signals have been given and observed by *coincidence*.

In order to obtain an additional control on the longitude of Durban, and thence on the personal equation of F. and M., I took advantage of a visit which Mr. Pett was about to make to Natal in July 1882. The Durban hut with its transit and clock were accordingly left *in situ*, in charge of the Government clerk of works.

Before and after his visit to Durban Mr. Pett determined his personal equation relative to Mr. Finlay, both observers using the three-inch Transits.

The results obtained were

	F.–P.
Before the departure of P.	+0·000
After the return of P. ...	+0·040
Mean	+0·020

After the application of all corrections for personal equation so derived, the following results were obtained:—

Cape Transit Circle West of Durban Hut.

Observers.	Date.	h m s
I. Finlay, at Durban Maclear at Cape	June 1881	0 50 12·148 on 4 days. ± ·025*
II. Finlay at Durban Pett and Freeman at Cape with Transit Circle	June 1881	12·176 on 4 days. ± ·018*
III. Maclear at Durban Pett and Freeman at Cape with Transit Circle	Aug. & Sept. 1881	12·199 on 3 days. ± ·022*
IV. Maclear at Durban Finlay at Cape	Dec. 1881 & Jan. 1882	„ „ 12·196 on 3 days. ± ·017*

* These so-called "probable errors" are merely deduced in the usual way from the agreement of the separate results of each operation.

Observers.	Date.	h m s
V. Maclear at Durban Freeman and Pett at Cape with Transit Circle	Dec. 1881 & Jan. 1882	0 50 12·192 on 6 days. ± ·030*
VI. Pett at Durban Finlay at Cape Both using 3 in. Transits	July 1882	12·152 on 2 days. ± ·004*

In these six operations the personal equations have been applied as follows:—

I. and II.	F. = +0·150 =	His equation as determined before leaving the Cape.
IV.	F. = +0·110 =	His equation as determined after his return.
I. and III.	M. = +0·007 =	" " before leaving.
IV. and V.	M. = +0·047 =	" " after his return.
VI.	F. − P. = +0·020 =	Mean of their relative equation as determined before and after Mr. Pett's visit to Durban.
II. III. and V.	$\frac{P. + I.}{2} = -0·079$ =	Constant.

To obtain the most probable value of the difference of longitude Durban—Cape, it will be perhaps best to give equal weight to the observations of the most strictly separate determinations, viz. :—

Cape (Transit Circle West) of Durban (Transit Hut).

			h m s
Finlay at Durban,	I. and II.	=	0 50 12·162
Maclear ,,	III. IV. and V.	=	12·196
Pett ,,	VI.	=	12·152
		Mean	0 50 12·170

It will now be convenient to give the separate results for the difference of longitude Aden—Durban. They are as follows :—

Durban, West of Aden (uncorrected).

		h m s
VII.	Aug. 20	0 55 48·71
	23	48·59
	Sept. 2	48·43
	13	48·60
	18	48·32
	19	48·575
	22	48·45
	23	48·65
	26	48·53
	28	48·45
		0 55 48·531

* These so-called "probable errors" are merely deduced in the usual way from the agreement of the separate results of each operation.

We have besides these the following results of direct comparison with the Cape, Durban having no observations on these nights:—

Cape Transit Circle West of Aden.

		h m s		
VIII.	Aug. 26	1 46 0·69	Cape Observers, P. and I.	
	27	0·53	„	„
	Sept. 3	0·75	„	P.

These results are without correction for personal equation.

In order to discuss the all-important question of the personal equation of Mr. Finlay at Aden, I adopt as definitive the above-found value of the longitude of the Cape west of Durban. Then for the mean of operations I. and II. we get for the seconds of the longitude in question $12^s \cdot 162$, which would imply that at the time in question Finlay's adopted personal equation required the further correction $+ \cdot 008$, that is

In June 1881 $\quad$ F. = $+0^s \cdot 158$ ... ... (1)

From operation III. the seconds of the longitude are $12 \cdot 199$, which would imply that at the time in question Maclear's adopted equation required the correction $-0^s \cdot 029$, that is—

In Aug. and Sept. 1881 $\quad$ M. = $-0^s \cdot 022$ ... (2)

The operations IV. and V., from their agreement with the result of operation III., appear to show the reality of the change of $+0^s \cdot 040$ in Maclear's personal equation between September and December 1881, and that Maclear's personal equation for the latter period requires a correction of $-0^s \cdot 024$, that is—

In Dec. 1881, and Jan. 1882 $\quad$ M. = $+0^s \cdot 023$ ... (3)

When Mr. Finlay returned to Durban from Aden he compared personal equation with Mr. Maclear on four nights with the result—

In Nov. 1881 $\quad$ F. − M. = $+0^s \cdot 208$ ... (4)

If we suppose Mr. Maclear's habit of observation to have changed gradually between September and December, we cannot be far wrong in adopting from (2) and (3)—

In Nov. 1881 $\quad$ M. = $+0^s \cdot 010$, and hence from (4)

„ $\quad$ F. = $+0 \cdot 198$ ... ... (5)

We have from (1) and (5)—

In June 1881 $\quad$ F. = $+0^s \cdot 158$

Nov. „ $\quad$ F. = $+0 \cdot 198$

And I adopt the mean of these as the most probable value of Mr. Finlay's personal equation at Aden in August and September.

We have, therefore, for the personal equation of F. and M. during the exchange with Aden—

$$\left.\begin{array}{ll}\text{In Aug. and Sept. 1881} & \text{F.} = +0^{s}\cdot178 \\ \quad\text{,,} & \text{M.} = -0\cdot022\end{array}\right\} \quad \ldots \quad (6)$$

The results of operation VII. will therefore require the following corrections:—

	Corresponding Correction to Difference of Longitude.
	s
Correction of $-0^{s}\cdot261$ to Maclear's time of recording submarine signals	$+0\cdot131$
Correction for Finlay's personal equation in determining time (6) ($+0^{s}\cdot178$)	$+0\cdot178$
Correction to same on account of reversal of direction of star's apparent movement in the northern hemisphere ($+0^{s}\cdot070$)	$+0\cdot070$
Correction for Maclear's personal equation in determining time ($-0^{s}\cdot022$)	$+0\cdot022$
	$+0\cdot401$
Uncorrected result of operation VII. ...	0 55 48·531
Add Cape, West of Durban	0 50 12·170
Hence Cape, West of Aden	1 46 1·102

The three results of operation VIII. all require the first three corrections of No. VII. The results of August 26 and 27 require, besides, the correction

$$-\frac{\text{P.}-\text{I.}}{2} = +0^{s}\cdot079,$$

and the result of Sept. 3 requires the correction

$$-\text{P.} = -0^{s}\cdot033.$$

So corrected, the separate results become:—

Cape Transit Circle, West of Aden.

		h m s
Aug. 26		1 46 1·148
27		0·988
Sept. 3		1·096
	Mean	1 46 1·077

It is almost needless to discuss the relative weight that should be given to these two closely accordant results, for it must

be remembered that the personal equation adopted for Maclear in operation VII. depends on exchanges with the Cape on only three nights.

Had Mr. Maclear's personal equation been supposed constant during his stay at Durban (which, in view of the probable errors of the separate determinations, is not an inadmissible supposition), and accepting $0^h\ 50^m\ 12^s{\cdot}170$ for the definitive difference of the longitudes of Durban and the Cape, we should have as the personal equation of Maclear—

$$M. = +0{\cdot}008 \text{ during his stay at Durban,}$$

and this would make the personal equation of Finlay—

In Nov. 1881	F. = $+0{\cdot}200^s$	Mean $+0{\cdot}179$
and as before in June ,,	F. = $+0{\cdot}158$	

The former results of operations VII. and VIII. would then require the corrections $-0^s{\cdot}029$ and $+0^s{\cdot}001$ respectively, and would become:—

Cape Transit Circle, West of Aden.

		h m	s
By operation VII.	... ...	1 46	1·073
,, VIII.	... ...		1·078

It is obvious from these considerations that if we take the mean of the two solutions of operation VII. we adopt the mean of the almost equally probable hypotheses, and in consideration of the number of observations in operation VII., we may allow it double weight.

We have thus definitively—

		h m	s	
From operation VII.	... ...	1 46	1·087	wt. 2
,, VIII.	... ...		1·078	wt. 1

whence—

	h m	s
Cape Transit Circle, West of Aden	1 46	1·084

Economic considerations prohibited the exchange of observers at Aden, and therefore the chief uncertainty of the final result must be the personal equation of the observer at Aden. The results of Mr. Finlay's personal equation, determined at Aden two months before and two months after the Aden observations, differ only $0^s{\cdot}04$, and I think it extremely improbable that his true personal equation at Aden differed by this amount from the adopted mean.

The case will probably be met by assigning to the whole operation a probable error of $\pm 0^s{\cdot}03$. Beside such an error the accidental errors of the operation are comparatively insignificant —their rigid computation is therefore unnecessary.

The site of the station at Aden is the same as that occupied by the Royal Engineers of the G. T. Survey of India, in their connection of the Longitude of Bombay with that of Sir George Airy's Transit of *Venus* Station (Hunter's Station) at Suez. I accept the result of General Walker as quoted in Annual Report of the G. T. Survey of India, 1876–77, viz.—

		h	m	s
Aden, East of Hunter's Station, Suez	...	0	49	42·656

The Longitude of Hunter's Station, Suez, depends on the operations described in the "Account of the Observations of the Transit of *Venus*," British observations of 1874, edited by Sir Geo. B. Airy, of which the result is given on page 346 of that work, viz.—

		h	m	s
Hunter's Station, East of Greenwich	...	2	10	13·17

Combining these results, we have—

		h	m	s
Hunter's Station, East of Greenwich	...	2	10	13·17
Aden, East of Hunter's Station ...	...	0	49	42·656
Aden, East of Greenwich	...	2	59	55·826
Cape Transit Circle, West of Aden, as determined in the present paper ...	...	1	46	1·084
Cape Transit Circle, East of Greenwich	...	1	13	54·742

It is not probable that the result for "Cape, West of Aden" will be sensibly changed by further discussion, or by the small corrections that may yet be due to improved places of some of the Northern Circumpolar Stars. The absolute value "Cape, East of Greenwich" may yet be sensibly modified when the definitive discussions of the Longitude operation in connection with Lord Lindsay's and the German Expedition to Mauritius have been published, but I do not think that the difference will be of consequence for Transit of *Venus* purposes.

The Secondary Longitudes on the East Coast of Africa, which form the subject of a separate paper by Mr. Finlay, have been undertaken as a labour of love, and carried out by him with much spirit and energy.

I cannot conclude this paper without an expression of my grateful thanks :—

(1) To Sir James Anderson, who most generously placed the submarine cables between Aden and Durban entirely at my disposal for this work.

(2) To James Sivewright, Esq., C.M.G., General Manager of Telegraphs at the Cape, for not only placing the whole South African system of land-lines at my

disposal, but also for making all the necessary arrangements, and supplying all necessary aid. Also for the exact execution of this work to Mr. J. P. Edwards, his able and active assistant.

(3) To H. Carlisle, Esq., and C. Stacey, Esq., the superintendents at Durban and Aden, not only for the efficient aid they rendered, but for their kindly hospitality to all engaged in the work.

(4) To H. McEwen and A. W. Prosser, Esq., members of the telegraph staff at Durban and Aden respectively, for the active share which they took in the work, for the intelligent interest which they displayed, and for the great enhancement of its value which resulted from their labours of love.

Elliptic Elements of Comet b, 1882. By John Tatlock, Jun.

(*Communicated by Prof. T. H. Safford.*)

The present orbit is communicated as of possible interest, in comparison with the orbits of Dr. Kreutz and Prof. Frisby, with regard to the indications of the motion of the comet after it had passed perihelion. It was arranged for computation before Dr. Kreutz's elements, contained in No. 2482 of the *Astron. Nach.*, came to hand, as the copy of that number intended for this institution was lost in the "Cimbria." Had I seen his orbit sooner I should have made some changes in the dates of the places from which my orbit was computed. As it is, however, the date of my third place is 76 days later than the date of Dr. Kreutz's third place, and 66 days later than that of Prof. Frisby's. This fact will probably account for some of the discrepancies between the orbits of the above-named gentlemen and my own.

The elements are as follows, the computation being made by Gauss' method, as given in the *Theoria Motus* :—

Comet b, 1882.

T	=	Sept. 17·14302	
Log. q	=	7·9164079	
ω	=	70° 2′ 23″·16	Mean Equinox 1882·0
☊	=	346 18 30·45	Mean Equinox 1882·0
i	=	142 3 28·22	Mean Equinox 1882·0
ϕ	=	89 20 18·35	
a	=	123·75	
e	=	·9999332	
P	=	1376·6 years.	

These elements result from the following normal places:—

Mean Equinox 1882·0.

G.M.T.		α	δ	No. of Obs.
		h m s s	° ′ ″ ″	
1882, Oct.	8·0	10 29 22·76 ± 0·140	−10 15 48·7 ± 4·06	21
Nov.	24·0	9 8 32·92 ± 0·237	−27 7 2·9 ± 1·22	16
1883, Jan.	29·0	6 13 34·56 ± 0·241	−22 54 19·5 ± 2·22	16

The probable errors given above are only approximate, as the changes which took place in the nucleus and the different parts of the same used by different observers would preclude any definite determination of their values.

Field Memorial Observatory of Williams College,
Williamstown, Mass., U.S.A.

Astrophysical Observations made during the Year 1882 *at the Herény Observatory, Hungary.* By Eugen de Gothard.

(*Communicated by Dr. N. de Konkoly.*)

Spectroscopic Observations.

In the year 1882 the spectra of 147 fixed stars and of two comets have been observed; the former with a small Zöllner ocular spectroscope, with one set of three prisms and a cylindrical lens; the latter with the same apparatus with a slit, the cylindrical lens being omitted.

On the appearance of the great September comet I endeavoured to perfect the instrument afterwards used for observing faint spectra. It consists of a Merz half-prism, movable by a fine micrometer screw; a bright line formed by a narrow slit in the focus of a small lens serves as an index. The table giving the motion of the micrometer screw in wave-lengths was constructed by a graphical method, from observations of nineteen known lines in the solar spectrum, made onNovember 6.

Out of the 147 stars mentioned above, the details are given only of 43 stars not included in Secchi's Catalogue.

Classification of Star-Spectra observed during the year 1882.

(Dr. Vogel's types.)

No.	Constellation.	Type I *a*.	Type II *a*.	Type III *a*.	Diff. and uncertain types.	Total
1	Cassiopeia	β, δ, ϵ	α		γ	5
2	Cepheus	α	γ		β	3
3	Perseus	β, δ	$\alpha, \gamma, \epsilon, \eta, \kappa$?	ρ	ζ, ν, τ, θ	12
4	Auriga	β, θ	α	π		4
5	Ursa major	β, ζ Alcor. ϵ, η, δ ?	α			8
6	Boötis	γ	δ			2
7	Corona bor.	α, β			θ	3
8	Hercules	$\delta, \epsilon, \iota, \nu, o, \rho, \sigma, \tau, \phi, \rho$	β, λ, π, ξ ?	α	$\gamma, \zeta, \mu, \theta, \upsilon$	20
9	Lyra	$\alpha, \beta, \gamma, \zeta, \epsilon$, 16 Fl.		δ, 13 Fl.		8
10	Cygnus			Birm'ham		1
11	Andromeda	α, μ	γ, δ	β		5
12	Triangulum	β	α			2
13	Aries	β, γ, 14 Fl.	α	35 Fl.		5
14	Taurus	β, η, 17, 27 Fl.		α		5
15	Gemini	α, γ	β		δ	4
16	Canis. min.	α, β				2
17	Leo	$\alpha, \beta, \delta, \zeta, \sigma$	γ		η	7
18	Serpens	δ, ϵ, μ	α, η, θ			6
19	Ophiuchus	$\alpha, \gamma, \eta, \iota, \lambda, \nu$, 72 Fl.	$\beta, \epsilon, \kappa, \sigma$, 68 Fl.	δ	ζ, o, 70 Fl. Com. III. 6	17
20	Aquila	α, λ, θ	γ, η			5
21	Delphinus	ζ				1
22	Pegasus	α, θ	β, ϵ		γ (I. 6?)	5
23	Scorpius			α		1
24	Sagittarius	$\delta, \lambda, \mu, \pi, \rho, \sigma$	ξ		ζ	8
25	Scutum. Sob.		7 H. 3 H		6 H.	3
26	Capricornus	δ	β			2
27	Aquarius	γ	α, β			3
28	Pisces austr.	α				1
28		77	38	11	21	147

Number of observations, 169. Number of days, 8.

March 15 and 16, June 17, July 15 and 24, August 7, and September 4 and 5.

Stars not in Secchi.

θ *Coronæ bor.*, mag. 4, bluish-white.
I endeavoured in vain to see some lines in the spectrum of this remarkable star.

ϕ *Herculis*, mag. 4, bluish-white.
$H\beta$, $H\gamma$, and D, very strong. I. *a*.

τ *Herculis*, mag. 3–4, bluish-white.
$H\beta$ and $H\gamma$ rather faint, but observed with certainty. I. *a*

σ *Herculis*, mag. 4, bluish-white.
The intensity of $H\beta$ and $H\gamma$ is characteristic. I. *a*.

π *Herculis*, mag. 3–4 yellow.
The spectrum very much resembles that of the Sun. II. *a*.

ϵ *Herculis*.
Spectrum faint, but $H\beta$ and $H\gamma$ distinctly visible. I. *a*.

ι *Herculis*, mag. 3–4, bluish-white.
$H\beta$ and especially $H\gamma$ very strong. I. *a*.

13 *Fl. Lyræ*, mag. 5–4, orange.
There are two bands both in the red and green part of the spectrum, and three in the blue. They are sharply defined towards the violet. III. *a*.

16 *Fl. Lyræ*, mag. 5, bluish-white.
Resembles the spectrum of γ *Lyræ*, but is fainter. I. *a*.

Birmingham red star, R.A. $20^h\ 36^m\ 38^s$, D. $+47°\ 37'\!\cdot\!6$, mag. (var.) 8.
Colour intense red, the spectrum tolerably brilliant, with broad bands in the red, yellow, and blue. III. *a*.

35 *Fl. Arietis*, mag. 5, yellow.
The ultra-violet intersected by many bands. III. *a*.

14 *Fl. Arietis*, mag. 4–3, bluish-white.
I noted $H\beta$, $H\gamma$, and the faint D. I. *a*.

17 *Fl. Tauri*, mag. 6, bluish-white.
$H\beta$ and $H\gamma$ very well seen. I. *a*.

27 *Fl. Tauri*, mag. 4, bluish-white.
Identical with the spectrum of η *Tauri*. I. *a*.

δ *Serpentis*, mag. 3–4, white.
Hydrogen lines very strong. I. *a*.

η *Serpentis*, mag. 3, yellow.
Besides D and F there are other groups of lines. II. *a*.

θ *Serpentis*, mag. 4–3, yellow.
Identical with the former. II. *a*.

ζ *Ophiuchi*, mag. 3–2, bluish-white.
A very intense continuous spectrum, only D glimpsed occasionally. I. *b*.

ι *Ophiuchi*, mag. 4–5, bluish-white.
Hβ and Hγ very distinctly visible. I. *a*.

κ *Ophiuchi*, mag. 3–4, yellow.
Besides D and F, several other faint lines are visible. II. *a*.

η *Ophiuchi*, mag. 2–3, bluish-white.
Hα, Hβ, and Hγ, distinctly seen. I. *a*.

σ *Ophiuchi*, mag. 5, yellow.
D and F very distinct; other lines suspected in the green. II. *a*.

β *Ophiuchi*, mag. 3, yellow.
Strongly resembles the solar spectrum; D, b, and G were distinctly noted. II. *a*.

γ *Ophiuchi*, mag. 4–3, bluish-white.
Brilliant spectrum with strong Hβ and Hγ. I. *a*.

ν *Ophiuchi*, mag. 4–3, white.
Characterised by very broad hydrogen lines. I. *a*.

68 *Fl. Ophiuchi*, mag. 4–5, white.
Though the spectrum is feeble, the characteristic hydrogen lines are distinctly visible. I. *a*.

72 *Fl. Ophiuchi*, mag. 3–4, bluish-white.
Intense spectrum with Hβ and Hγ. I. *a*.
Between 70 Fl. and *o Ophiuchi* is a star of 7th mag., with a continuous spectrum of great intensity. The colour of the star is brick-red.
Latterly I could not find this star again, though I determined its situation and registered it in the atlas.

λ *Aquilæ*, mag. 3–4, bluish-white.
Hβ and Hγ very intense. I. *a*.

η *Aquilæ*, mag. var., yellow.
Its faint spectrum resembles that of the Sun. II. *a*.

θ *Aquilæ*, mag. 3, bluish-white.
Faint spectrum, with intense F and a fainter Hγ. I. *a*.

θ *Pegasi*, mag. 3–4, bluish-white.
The spectrum is characterised by broad Hβ, Hγ. I. *a*.

μ *Sagittarii*, mag. 4, bluish-white.
Though the spectrum is very feeble, Hβ and Hγ are distinctly visible. I. *a*.

δ *Sagittarii*, mag. 3–4, bluish-white.
Intense violet and dark hydrogen lines. I. *a*.

λ *Sagittarii*, mag. 3, bluish-white.
Intense spectrum, with strong hydrogen lines. I. *a*.

ξ *Sagittarii*, mag. 4, yellow.
Characterised by a dark D and intense F, and also by many faint lines in the green. II. *a*.

ρ *Sagittarii*, mag. 4, white.
Resembles the spectrum of π *Sagittarii*, with strong Hβ and Hγ. I. *a*.

Observations of Comets.

Comets *Wells* and *Barnard* have been observed with but little success.

Measures have only been made of the spectrum of the great September comet. The result of all the observations is as follows:—

Date.	Wave-length in mm. I.	II.	III.	No. of Obs.
Nov. 1	561·6	514·9	471·5	4
3	561·5	514·5	470·7	5
6	563·4	515·8	469·6	8
7	562·6	516·0	470·9	10
10	561·8	515·4	471·6	10
11	560·9	515·3	471·7	10
12	562·0	515·4	470·9	10
18	561·4	515·4	471·3	5
Mean ...	561·9	515·3	471·0	62

Comparing these results with those obtained by Dr. de Konkoly ("On the Chemical Constitution of Comets," Royal Hungarian Academy) we obtain the following differences:—

Results of my observations	561·9	515·3	471·0
Mean of all De Konkoly's observations	560·9	515·6	469·5
Difference	+1·0	−0·3	+1·5

The intensities of the bands were estimated at 0·2, 1·0, 0·5, on November 1.

Observation of the Solar Eclipse 1882, *May* 16.

	h m s	
First contact	19 0 12·2	Eugen de Gothard
	19 1 1·5	Alexander de Gothard
Last contact	20 47 56·2	Mean $20^h\ 47^m\ 58^s{\cdot}5$ H.M.T.
	48 0·8	

Alexander de Gothard observed the first contact a little too late. Instruments: the 10¼-inch Browning Reflector, with a reduced aperture of 6 inches, and an achromatic telescope by Bardon et Fils, of Paris.

During the eclipse six successful photographs were obtained.

[These photographs are deposited in the Society's Library.]

Physical Observations of Jupiter and Mars made during the Year 1882 at the Astrophysical Observatory, Herény, Hungary. By Alexander de Gothard.

(*Communicated by Dr. N. de Konkoly.*)

The total number of observations of *Jupiter* made this year was 36; 29 belong to the opposition of 1881–82, and seven to the beginning of the opposition of 1882–83.

A great difference is at once perceived between the drawings made in spring and autumn; and this difference is based on real changes.*

The typical distribution of the bands was always the same in the first half of the year. There were visible three chief bands —an equatorial, a southern, and a northern one. For the second half of the year such uniform distribution no longer prevailed. The colour of the equatorial band had on every occasion a certain characteristic rusty-red tone, with very variable shadings.

The form of this band is also changing, but its division and fringing are almost exclusively confined to its southern border.

The colour of the southern band is a faint grey; most of it consists of ashy branches, forming small stripes and prominences, appearing only on its equatorial side; therefore the zone between these two bands shows the most detail and variety. Under the red spot this southern band always appears narrower or curved.

The form and colour of the northern band are very constant; the colour is generally a drab of a feeble greenish tone. The poles of the planet are covered sometimes with a grey nebulous veil of variable extent, the boundary of which is sometimes sharp and sometimes faint.

The red spot is sometimes surrounded by a brilliant white zone. It is almost constantly accompanied by a dark grey cloudy line, narrowing towards the equator to a triangular figure, thus forming the boundary of the above-mentioned bright zone.

On most occasions I observed that the form of the red spot was elliptical; sometimes it is bounded by lines parallel with the major axis, the ends of which are united by half circles.

The colour of the red spot varies very much; sometimes it appears of a dirty flesh colour, at others of a feeble red tint. In the autumn observations it was not visible, so that I began to think it had disappeared. In the spring of 1883 I saw it again, though of an exceedingly pale colour; it was therefore only the unfavourable atmospheric conditions that caused its invisibility. Nevertheless I conclude that the phenomenon is disappearing; and I think there is little hope of finding it again in the opposition of 1884.

* The drawings of *Jupiter* and *Mars* are exhibited in the Society's Library.

In general but little can be said about the observations of the second half of the year; the surface of the planet shows so great a variability that no resemblance can be found between the drawings. But it was remarked that the equator was always covered with a greenish-yellow zone, extending from one-fourth to one-third of the minor axis of the disk, and filled with irregular clouds and nebulosities. The poles were always surrounded by a dark shade.

The instrument with which the observations have been made is the 10¼-inch Browning-Newtonian Reflector.

The description of the drawings of *Mars* is much more difficult than of *Jupiter*, as well-defined spots can only be seen with good definition. Thus but little remains to say of the observations.

In January and February of the year 1882 nine observations and drawings were made. Some of the drawings show well-defined spots of great extent.

The colour of the markings is more decided towards the centre of the disk. Here the greyish-green markings contrast very strongly with the red portions of the disk, and thus appear well defined.

Towards the limb the colours are paler and feebler, no part being at all defined.

The northern ice-cap was distinctly visible on all occasions, surrounded by a ring of bright white colour.

Eugen de Gothard believed that he twice glimpsed one of the satellites: viz. on February 5, $8^h\ 0^m$ H.M.T., when he saw an exceedingly small starlike point at a distance of about 2·5—3 *Mars*-diameters from the disk in the N.W. direction; and on February 9, $8^h\ 15^m$ H.M.T., when a bright point was noticed on the S.E. side of the planet at about the same distance. The magnifying power was 436.

Note on the Chromosphere. By the Rev. S. J. Perry, F.R.S.

A letter appeared in the *Observatory* a few months since containing a communication from Professor Respighi on the subject of the Chromospheric Lines between A and C, and a wish was expressed that English observations bearing on his results might be brought before the public. I have therefore thought it worth while to bring under the notice of the Fellows of the Society an observation taken a few days ago.

On May 30, whilst taking the usual daily measures of the Chromosphere, my assistant at Stonyhurst Observatory, Mr. W. McKeon, observed the bright line Kirchoff 654·3 between C and B. It was only visible near the point 63° 58′ E. of N., image direct. Sweeping round the Sun's limb the chromosphere became suddenly intensely bright at this point, and also very wide, and an

extraordinary bright cloud, displaced towards the less refrangible portion of the spectrum, appeared near the upper end of the C line. The line K 654·3 was almost as bright as C, but was not displaced. This brilliant portion of the chromosphere proved to be the beginning of a large prominence, and as the prominence increased in height the line K 654·3 faded away, becoming invisible where the prominence was highest and brightest. On sweeping back to the former position the bright cloud was found to have disappeared, and both C and K 654·3 were somewhat less brilliant than before.

The solar drawing on June 2 shows that a moderately large group of spots was just on the limb at the point where K 654·3 was seen on May 30. Another larger group of spots has burst out since May 30, and is already past the centre of the disk.

Stonyhurst Observatory:
1883, *June* 5.

Note with respect to the Limb of the Planet Jupiter.
By A. C. Ranyard, M.A.

At a recent meeting of the Astronomical Society Capt. Noble stated that, in observing an eclipse of *Jupiter's* fourth satellite on April 4, 1883, he was struck with the slow manner in which the light of the satellite disappeared and flashed up again at intervals, so brightly that he could not persuade himself that the changes of light were due to scintillation or disturbance in the Earth's atmosphere. Mr. Marth showed that the slow disappearance was due to the fact that the satellite, on the occasion referred to, entered the northern edge of the cone of shadow cast by the planet very obliquely; but the flashing up again of the light of the satellite at intervals was not explained. Direct observations of *Jupiter* point to the existence of an extensive atmosphere in which great masses of cloud are suspended, I would suggest that the flashing up at intervals of the light of the satellite was due to its passage through darker regions in the penumbra of the planet's shadow caused by clouds in the atmosphere of *Jupiter*. The oblique passage of the satellite through the penumbral region of the shadow, probably causing the changes of illumination to last for a longer period than on ordinary occasions, when the satellite plunges more perpendicularly into the cone of shadow.

The object of the present note is to bring together some observations of eclipses of *Jupiter's* satellites and occultations by the limb of the planet, which tend to show that *Jupiter* has not a definite, hard outline, but that the limb is partially transparent with here and there regions of greater opacity.

Dr. T. D. Siminton, of St. Paul, U.S.A., observed the previous eclipse of the fourth satellite. On that occasion the

satellite only just grazed the northern edge of the shadow cone. An account of the observation is given in the *Sidereal Messenger* for April 1883. Dr. Siminton says: "The light of the satellite rapidly decreased till $10^h\ 55^m$, when, if visible at all, the light of the body was excessively faint. This continued but a minute or two, when I was sure of it again by glimpses, and in a minute or two more, before $11^h\ 0^m$, I could see it steadily." The observation was made with a 3-inch achromatic.

On April 26, 1863, Mr. S. Gorton observed an occultation of the second satellite. An account of the observation is given in the *Monthly Notices*, xxiii. p. 217. He says "the occultation occupied nearly seven minutes, during which time, owing apparently to the movement of the atmosphere, the satellite seemed to disappear and appear again several times."

On October 5, 1878, Mr. Todd, the Director of the Adelaide Observatory in South Australia, observed an eclipse of the fourth satellite. An account of the observation is given in the *Monthly Notices*, xl. p. 175. He says in a note with respect to the time of disappearance: "Time considered exact, but lost sight of satellite several times before final disappearance; planet not well defined; Moon a little to east of planet."

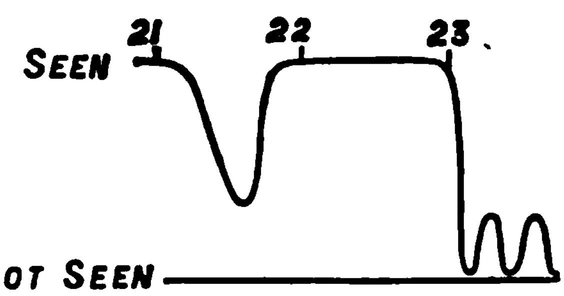
On Sept. 14, 1879, Mr. J. Turner observed an occultation of 64 *Aquarii* with the great Melbourne Reflector and a power of 350. An account of the observation is given in the *Monthly Notices*, xl. p. 141. He says: "At the moment of contact the star did not instantly disappear, but seemed to possess a visible disk, the limb of *Jupiter* seeming to advance gradually upon it, the star, by-and-by, appearing to be bisected and then gradually disappearing altogether. The time of final disappearance was $10^h\ 7^m\ 47^s{\cdot}6$ M.M.T., at which instant the circle of *Jupiter's* limb appeared perfect; previous to this the star appeared as a small protuberance upon the limb, which *gradually* got smaller until final disappearance. The time of first contact was not noted, but I estimated the interval between contact and disappearance at about 35 seconds; certainly not less, it might be more. For about 10 seconds after disappearance the star could be seen *through Jupiter's* atmosphere as a speck of light seen through ground glass. This also disappeared *gradually*. There was no fitful disappearance and reappearance, but gradual disappearance throughout. . . . At $12^h\ 34^m\ 47^s$ I could clearly see a minute protuberance where the star was expected to appear. This protuberance exactly resembled the one-half of the disk-like appearance of the star at disappearance [the planet was then hidden by clouds and] at $12^h\ 37^m\ 57^s$ I got another clear view for about 10 seconds, when the star was seen well separated from *Jupiter*. The small protuberance noted three minutes previously was thus proved to be the reappearance of the star."

The same occultation was observed by Mr. Ellery with an 8-inch achromatic, power 300. He says: "The star first appeared to touch the planet's limb at $10^h\ 5^m\ 19^s$ M.M.T., and was

visible in that position for nearly two minutes, when, while still making a projection on the planet's outline, it all at once appeared as if seen through a mist or haze, *and entirely projected on the planet's limb.* This faded away in about ten seconds, leaving still a decided nipple-like projection on the edge of the planet, as if the planet itself bulged out, without any signs of the true light of the star; and at $10^h\ 7^m\ 43^s{\cdot}8$ this disappeared, leaving a clean outline to the disk."

Mr. E. J. White, of the Melbourne Observatory, who observed the occultation with a 4½-inch achromatic, says that "Although the definition was very good in a cloudless sky, yet slight oscillations of the planet occurred which made the star momentarily disappear. At $10^h\ 6^m\ 23^s{\cdot}7$ M.M.T. I thought the star had really disappeared; but on looking again I saw it projected on *Jupiter* as a bright nipple, which seemed to gradually lessen in size till $10^h\ 7^m\ 40^s{\cdot}4$, when I finally lost sight of it."

Professor E. C. Pickering has kindly communicated to me the following note with reference to an occultation of a 7·3 magnitude star which he observed on April 14, 1883. The star occulted was D. M. $+23^\circ{\cdot}1087$.



The diagram, which is made from a sketch given by Prof. Pickering, represents the variation in the intensity of the light of the star during the two and a quarter minutes before its final disappearance. His notes with respect to the observation run as follows:—

G.M.T. h m s		G.M.T. h m s	
14 21 17	Seen.	14 23 1	Not seen.
30	Seen with difficulty.	13	Suspected.
44	Suspected.	24	,,
48	Seen.	34	Not seen.

"For about two minutes before final disappearance the star alternately disappeared and reappeared without obvious cause; seeing pretty good and uniform throughout. For twenty-six minutes the planet was carefully watched, and the star was again seen at $14^h\ 49^m\ 56^s$. The uncertainty in this time must have been very small, as the observer had not removed his eye from the telescope for some time previously. The star continued visible without the fluctuations noticed at disappearance. The occultation occurred near the northern limb of *Jupiter*. E. C. Pickering (observer), A. Searle (recorder)."

The observation was made with the 15-inch achromatic of Harvard College Observatory.

On April 14, 1883, *Jupiter* moved through a little less than 11″ of arc in twenty-six minutes of time, its motion amongst the stars being nearly parallel to the planet's equator, but slightly northward. In the two minutes and a half, the time which elapsed between the first change in the intensity of the light of the star and its final disappearance, the limb of the planet moved through about 1″·08. Taking *Jupiter's* distance from the Earth on April 14 as 507,610,000 miles, an arc of 1″·08 would correspond to a motion of the planet's limb through 2,600 miles. Assuming *Jupiter's* equatorial semi-diameter at the date of the observation to be 16″·6, and its polar semi-diameter to be 15″·6, the rays from the star passed through the planet's atmosphere at the time when the first change of intensity was observed, at a height of 890 miles above the level at which the rays were last transmitted just before the light of the star was extinguished.

If *Jupiter* had no atmosphere, and its limb were opaque, the region of total shadow cast by the planet would lie within an elliptical *conocuneus*, with its base upon the planet and its apex line at a distance of nearly seventy millions of miles beyond *Jupiter*; at the distance of the fourth satellite (1,192,000 miles) the elliptic section of the total shadow would be surrounded by a zone of penumbral shadow about 2,080 miles wide. The satellite itself has a diameter of 2,900 miles.

A refracting atmosphere about the planet would, by curving the Sun's rays inwards, tend to diminish the area of total shadow; but the time occupied by the satellites in traversing the shadow cone shows that the horizontal refraction of the Jovian atmosphere cannot be great at the height at which the Sun's light is extinguished in passing through the limb of the planet. There will always be some uncertainty as to the observed diameter of the shadow cone, for the satellites probably disappear before the Sun's disk is wholly eclipsed on the last portion of the disk of the satellite which enters the shadow. Observations of eclipses of our own Moon show that the Earth's shadow appears larger than the geometrical shadow which would be cast by a body as large as the Earth not surrounded by an atmosphere. Mädler estimated this increase of diameter as $\frac{1}{54}$th* (see *Astr. Nach.* xv. p. 29), and we know that clouds in our own atmosphere seldom, if ever, float at a height of ten miles above the sea level.

The Sun's disk at the distance of *Jupiter* has a diameter of less than 6′; and when the fourth satellite passes centrally through the shadow cone, any point on the satellite occupies about six and a half minutes in traversing the penumbral region.

* Mr. Godward informs me that the *Nautical Almanac* uses the fraction $\frac{1}{50}$ as representing the increase in the diameter of the observed shadow over the geometrical shadow thrown by the Earth. In the case of *Jupiter's* satellites, the predictions of eclipses are given as calculated for the geometrical shadow.

The satellite traverses its own diameter of 2,900 miles in about nine and a half minutes.

Taking into account the degradation of brightness towards the Sun's limb, we can hardly suppose that the Sun's light would be diminished so that the satellite would be lost sight of while a section of the Sun's disk with a versine of 1''·5 remained visible at a point half-way between the centre of the satellite and the following limb—that is to say, four minutes before the geometrical eclipse of the last portion of the Sun's disk at the following limb of the satellite. But even with the tables at present in use the predicted times for central eclipses of the fourth satellite do not differ from the observed times by as much as four minutes. We may consequently be sure that the horizontal refraction in the atmosphere of *Jupiter* at the height where the last ray is transmitted does not amount to 4' of arc.

I would suggest that the spectrum of the light of the satellites should be examined as they disappear in the shadow of the planet, to see whether any evidence of absorption can be detected due to the long passage of the illuminating rays through the atmosphere of *Jupiter*.

Observations of U Monocerotis and LL 14551, with a new Photometer. By the Rev. T. E. Espin, B.A.

The following observations of U *Monocerotis* were made with a photometer and opera-glass. The photometer was attached to the 5-inch Refractor, and is of simple construction; a beam of light is cut off by a circular stop, and leaves a disk of light on a dark field. The beam of light is totally reflected by a prism to the eyepiece end from a small oil lamp, that can be turned up or down at pleasure. So long as the eyepiece is in focus the star will be seen on the bright and dark background alike; but by gradually drawing out the tube, the image of the star becomes a disk, which up to a certain point will be seen on the bright part of the field; but when the eye-piece is drawn out beyond that point, it will be invisible, being lost in the brightness. Obviously the brighter the star the further the tube must be drawn out to reach the point of disappearance. The method employed in determining the magnitude of a variable star is to measure one star whose magnitude is known, and is greater than the variable, and one whose magnitude is known and less than the variable.

The distance the tube is drawn out is read off by a scale from a mark on the telescope to some mark on the draw tube. The variable star is then measured. The magnitudes of the two comparison stars being known, the difference of readings will equal the difference of magnitudes, and it becomes a matter of simple proportion to find the magnitude of the variable star. The variable star U *Monoc.* was discovered by Dr. Gould, of

Cordoba. The place in the *Uranometria Argentina* is (1875) R.A. $7^h\ 24^m\ 50^s$, Dec. $-9°\ 31'\cdot0$, and the period there is given as about 46 days. As far as I am aware there are no other published observations save those of the Cordoba Observatory. Though only two stars are necessary as comparison stars, four other stars have been measured occasionally to test the photometer, and do away with any errors arising from variation in the comparison stars.

The following are the places from the *Uranometria Argentina*:—

		R.A. 1875. h m s	Decl. 1875. ° ′	Mag. Ur. Ar.	Mag. Photom.
(1)	5 Puppis	7 42 6	−11 53·2	5·9	6·0 (assumed)
(2)	LL 15283	7 44 10	− 8 52·2	6·2	6·19
(3)	LL 14706	7 26 6	− 8 36·7	6·3	6·44
(4)	LL 14599	7 23 26	−10 4·2	6·2	6·52
(5)	W.B. 664	7 22 38	− 9 47·4	7·0	7·0 (assumed)
(6)	LL 14551	7 21 59	−11 18·3	6·3	var. 6·09 − 6·77

Of these stars, No. 2 was measured on five nights; the difference between the extremes being 0·27. No. 3 was measured on eight nights; the difference between the extremes being 0·10. No. 4, a suspected variable, was measured on fourteen nights; the difference between extremes being 0·24. While No. 6 was measured on twenty-one nights, and estimated on five others. This star is undoubtedly variable between 6·09 and 6·77. The following are all the determinations of magnitude I have obtained:—

LL 14551, *R.A.* $7^h\ 21^m\ 59^s$, *Dec.* 11° 18′·3. S. (1875).

	d	h	Mag.		
1883, Feb.	14		6·30		Measured
	15		6·20		,,
	23		6·19	6·09	Double set of measures.
Mar.	1		6·26		Measured.
	3		6·31		,,
	11		6·0		Estimated; clouds troublesome.
	12		6·51		Measured.
	13		6·67		,,
	14				Brighter.
	15		6·53		Measured.
	17	9	6·35		,,
	18	8½	6·42		,,

	d	h	Mag.		
1883, Mar.	23	9¾	6·54	6·59	Double set of measures.
	26	9½	6·54	6·47	"
	30	8¾	6·42	6·46	"
	31	9	6·55	6·54	"
Apr.	1	8½	6·30		Measured.
	3	8½	6·58	6·52	Double set of measures.
	6	9	6·64		Measured.
	7	8½	6·64		Estimated.
	8	8¾	6·46		Estimated; misty.
	11	8½	6·57		Estimated.
	12	9¼	6·50		Measured.
	16	9	6·77		"
	20	9	6·65		"
	22	8¾	6·55		Or less estimated.

The variation is undoubted, but the period seems to be irregular, or the observations not sufficient to determine it. This star is P. vii. 116 and Σ 1097. The magnitude of the bright companion being given by Σ as 6·5, but by Heis as 6. The first measures of U *Monocerotis* were made with the photometer on Feb. 14. Observations previous to this were made by estimations with an opera-glass. Occasionally two sets of measures were made, each measure being repeated three times.

U Monoc., R.A. 7h 24m 50s, *Dec.* 9° 31′·0 (1875).

Date. 1883.		Mag.		Date. d	h	Mag.		
Jan.	15	6·65	Estimated.	Feb. 22		6·78		Measured.
	18	6·60	"	23		6·45		"
	19	6·55	"	Mar. 1		6·22		"
	26	6·10	"	2		6·20		Estimated.
	27	6·00	"	3		6·19		"
	30	6·10	"	4		(1) 6·19	(2) 6·19	
Feb.	5	6·40	"	11		6·10		"
	10	6·80	"	12		6·40		Measured.
	12	6·65	"	13		6·57		"
	13	6·50	"	14		6·50		Estimated.
	14	6·40	Measured.	15		6·49		Measured.
	15	6·72	"	17		6·33		"
	18	6·77	"	18		6·53		"
	20	6·79	"	23	9¾	(1) 6·84	(2) 6·84	"

Date.			Mag.			Date.			Mag.	
	d	h					d	h		
Mar.	26	9½	6·70	6·65	Measured.	Apr.	7	8½	7·00	Estimated.
	30	8¼	6·92	6·91	,,		8	8½	7·20	,,
	31	9	6·94	6·98	,,		11	8½	7·05	,,
Apr.	1	8½	7·18		,,		12	9¼	6·85	,,
	3	8¼	7·00	7·05	,,		16	9	6·73	Measured.
	6	9	7·21		,,		20	9	6·65	,,
							22	8¾	6·50	Estimated.

From these we obtain as times of maxima—

1883, Jan.	28	6·00 ±	1883, Mar.	7 ±	6·00
Feb.	14	6·40	Mar.	17	6·33

And for times of minima—

1883, Feb.	10	6·80	1883, Mar.	13	6·57
	20	6·79	Apr.	6	7·21

At the minimum, March 31–April 11, there were small but well-marked fluctuations in light. The star did not seem hazy during this time, nor was there any perceptible change in the colour, which is yellowish-red. The total number of nights between the first and last observation is ninety-seven, and observations were obtained on forty-one.

West Kirby, Birkenhead:
1883, *June* 3.

Observations of Occultations of Stars by the Moon 1877–78, and of Phenomena of Jupiter's Satellites 1877, made at the Radcliffe Observatory, Oxford.

(Communicated by E. J. Stone, M.A., F.R.S.)

Occultations of Stars by the Moon.

Ref.	Day of Observation.	Phenomenon.	Moon's Limb.	Instrument.	Power.	G.M.T. of Observation. h m s	Observer.
(*a*)	1877, Jan. 30	Disapp. ρ Leonis	Bright	10-foot Equatorial	150	10 50 17·7	L.
		,,	,,	Heliometer	80	10 50 18·4	H.B.
(*b*)	30	Reapp. ρ Leonis	Dark	10-foot Equatorial	80	11 55 40·6	L.
(*c*)	Feb. 26	Disapp. Regulus	,,	,,	150	12 44 4·3	L.
(*d*)		,,	,,	Heliometer	80	12 44 2·9	Fd.B.
	26	Reapp. Regulus	Bright	10-foot Equatorial	150	13 49 43·6	L.
		,,	,,	Heliometer	80	13 49 43·5	Fd.B.
	Apr. 26	Disapp. 85 Virginis	Dark	10-foot Equatorial	150	11 59 33·5	L.
(*e*)	Aug. 23	Disapp. ✱ about 9 mag.	Eclipsed	,,	,,	9 45 1·2	L.
(*f*)		,, Lalande 43528-9	,,	,,	,,	10 29 40·3	L.
		,, ✱ about 9 mag.	,,	,,	,,	10 44 42·0 ±	L.
		,, ✱ ,, 8 ,,	,,	,,	,,	10 50 33·2	L.
		,, ✱ ,, 8 ,,	,,	,,	,,	10 53 27·8	L.
		,, ✱ ,, 9 ,,	,,	,,	,,	10 54 44·6	L.
		Reapp. ✱ ,, 10 ,,	,,	,,	,,	11 9 34·4	L.

Occultations of Stars by the Moon.

Ref.	Day of Observation.	Phenomenon.	Moon's Limb.	Instrument.	Power.	G.M.T. of Observation. h m s	Observer.
	1877, Aug. 23	Reapp. * about 9 mag.	Eclipsed	10-foot Equatorial	150	11 9 53·3 ±	L.
		Disapp. * " 9 "	"	"	"	11 21 2·9	L.
		Reapp. Lalande 43528–9	"	"	"	11 39 9·5 ±	L.
(g)	Nov. 20	Disapp. 16 Tauri	Bright	Heliometer	80	7 20 11·8	L.
		" 17 "	"	"	"	7 21 21 6	L.
		" 19 "	"	"	"	7 42 56·1	L.
		" 20 "	"	"	"	7 49 41·5	L.
	1878, Feb. 15	" ε Cancri	Imperfect	10-foot Equatorial	150	9 34 3·8	L.
(h)	Mar. 13	" 52 Geminorum	Dark	"	"	10 27 19·3	L.
(i)	16	" A Leonis	Imperfect	Heliometer	200	9 56 27·0	Fd.B.
(k)		" "	"	10-foot Equatorial	150	9 56 26·9	L.
	16	Reapp. A Leonis	Bright	"	"	10 34 17·4	L.

Remarks.

(a) and (b) Instrument unsteady; windy. (c) and (d) Instantaneous.

Aug. 23. These occultations observed during the eclipse of the Moon. Lal. 43528–9 noted as about mag. 7.

(e) "10^s going out of sight." (f) Seemed to hang on limb 3^s.

(g) The Moon full. All the stars became very faint at disappearance, 17 Tauri being less so than the others. Clouds were passing at the disappearance of 19 Tauri, but the observation is considered satisfactory. At 8^h 6^m 38^s ± G.M.T., two smaller stars were occulted nearly in the same place as 20 Tauri, but they became so faint at disappearance that the *exact* time could not be noted, although that given must be within two seconds.

(h) Cloudy, but the observation satisfactory. (i) and (k) Instantaneous.

In converting Oxford Mean Solar Times into Greenwich Mean Solar Times the following Longitude has been used, 5^m 2^s·6 W.

Phenomena of Jupiter's Satellites.

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation. h m s	G.M.T. of N.A. h m s	Obs.
	1877, June 20	I.	Tr. E. First contact	10-foot Equatorial	150	13 1 53		
			Bisection	"	"	13 3 58	13 6 0	Fd.B.
			Last contact	"	"	13 6 2		
(a)	July 5	I.	Oc. D. Bisection	Heliometer	200	11 37 13	11 38 0	Fd.B.
			Last contact	"	"	11 38 53		
(b)	7	III.	Oc. D. First contact	"	"	12 6 11		
			Bisection	"	"	12 9 10	12 10 0	Fd.B.
			Last contact	"	"	12 13 9		
	20	I.	Tr. I. Ext. contact	10-foot Equatorial	150	12 12 43	12 16 0	L.
			Int. contact	"	"	12 17 12		
	24	II.	Oc. D. First contact	"	"	11 7 4	11 11 0	L.
			Last contact	"	"	11 11 43		
(c)	26	II.	Tr. E. First contact	Heliometer	200	9 0 55		
			Bisection	"	"	9 4 54	9 3 0	Fd.B.
			Last contact	"	"	9 8 24		
	28	I.	Oc. D. First contact	"	"	11 18 51		
			Bisection	"	"	11 20 41	11 22 0	Fd.B.
			Last contact	"	"	11 22 40		

Phenomena of Jupiter's Satellites.

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
	1877, July 30	I.	Ec. R. First seen	Heliometer	200	8 56 32	8 56 37	Fd.B.
			Full brightness	„	„	8 57 13	—	„
	Aug. 5	III.	Ec. R. First seen	10-foot Equatorial	150	8 36 6	8 39 24	L.
			Full brightnes	„	„	8 42 5	—	„
	12	III.	Ec. D. Began to fade	„	„	9 50 55	—	L.
			Disappearance	„	„	9 56 25	9 55 32	„
	21	I.	Tr. I. First contact	„	„	8 22 37	8 25 0	L.
			Last contact	„	„	8 26 26		
	Sept. 7	I.	Ec. R. First seen	„	„	7 29 18	7 29 7	L.
			Full brightness	„	„	7 31 23	—	„
	22	I.	Tr. E. First seen	Heliometer	200	7 16 31	7 14 0	Fd.B.
			Last contact	„	„	7 22 0		
	Oct. 5	II.	Tr. I. First contact	10-foot Equatorial	150	7 17 3	7 17 0	L.
			Last contact	„	„	7 22 32		
	16	I.	Ec. R. First seen	„	„	6 1 28	6 1 35	L.
			Full brightness	„	„	6 3 25	—	„

Remarks.

(a) Planet ill-defined; observation unsatisfactory. (b) Images ill-defined and tremulous.
(c) Cloudy. Jupiter's image ill-defined; satellite unusually faint when near the planet. The shadow seen on the apparent lower belt.

Observers:—L. = Mr. Lucas. Fd.B. = Mr. Frederick Bellamy. H.B. = Mr. H. Bellamy.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Radcliffe Observatory, Oxford, 1882–83.

(*Communicated by E. J. Stone, M.A., F.R.S.*)

Occultations of Stars by the Moon.

Ref.	Day of Observation.	Phenomenon.	Moon's Limb.	Instrument.	Power.	G.M.T. of Observation. h m s	Obs.
(*a*)	1882, Mar. 22	Disapp. 53 Arietis	Dark	42-inch telescope	80	10 10 43·6	R.
(*b*)	Apr. 1	Disapp. *e* Leonis	Bright	10-foot Equatorial	160	11 33 17·3	R.
(*c*)	May 29	Disapp. B.A.C. 4700	Dark	"	160	13 1 27·1	R.
(*d*)	June 7	Reapp. κ Aquarii	"	42-inch telescope	80	12 20 4·8	R.
(*e*)	Aug. 2	Reapp. 22 Piscium	"	10-foot Equatorial	160	10 50 7·5	F.B.
(*f*)	Sept. 20	Disapp. μ Sagittarii	"	"	125	9 17 24·7	F.B.
	Oct. 24	Disapp. 51 Piscium	"	"	125	11 49 49·5	F.B.
(*g*)	1883, Feb. 15	Disapp. B.A.C. 1563	"	Heliometer	200	10 2 22·3	W.
(*h*)		"	"	10-foot Equatorial	160	10 2 22·2	R.
(*i*)	16	Disapp. χ^2 Orionis	"	Heliometer	200	5 58 45·8	W.
		"	"	10-foot Equatorial	160	5 58 45·8	R.
(*k*)		"	"	42-inch telescope	80	5 58 45·5	F.B.
(*l*)	Mar. 12	Disapp. *o* Arietis	"	Heliometer	80	6 49 35·1	W.
(*m*)		"	"	10-foot Equatorial	160	6 49 35·3	R.
(*n*)		"	"	42-inch telescope	80	6 49 34·8	F.B.

Remarks.

(*a*) and (*d*) Star exceedingly faint; observation difficult; Moon very low. (*b*) Lost in glare at Moon's limb.
(*c*) Disappeared instantaneously; observation considered very good. (*e*) The time noted may be a very little late.
(*f*), (*g*), (*h*), and (*i*) Instantaneous. (*k*) and (*m*) Instantaneous; but chronometer beats faint, noise from bells, &c.
(*l*) Disappearance instantaneous. Images very steady. "Earth-shine" very distinctly showed markings on the Moon; the star appeared to touch the "Earth-shine" limb at least two seconds before its sudden disappearance.

In converting Oxford Mean Solar Times into Greenwich Mean Solar Times the following Longitude has been used, $5^m\ 2^s{\cdot}6$ W.

Phenomena of Jupiter's Satellites.

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
	1882, Jan. 7	II.	Oc. D. Bisection	10 foot Equatorial	160	7 33 26	7 32 0	W.
	7	III.	Tr. E. Bisection	,,	,,	8 23 39	8 26 0	W.
			Last contact	,,	,,	8 32 58		
		I.	Tr. I. Ext. contact	,,	,,	8 27 9	8 27 0	W.
			Bisection	,,	,,	8 29 23		
			Int. contact	,,	,,	8 32 4		
	7	I.	Tr. E. Int. contact	,,	,,	10 35 45	10 40 0	W.
			Bisection	,,	,,	10 39 31		
			Ext. contact	,,	,,	10 41 59		
	23	I.	Tr. I. Ext. contact	,,	,,	6 38 11	6 39 0	R.
			Bisection	,,	,,	6 42 26		
			Int. contact	,,	,,	6 46 10		
	23	II.	Tr. I. Bisection	,,	,,	7 13 36	7 16 0	R.
			Int. contact	,,	,,	7 17 45		
(*a*)	24	I.	Ec. R. First seen	,,	,,	7 23 17	7 23 33	W.
(*b*)	Feb. 1	III.	Oc. D. Bisection	42-inch telescope	80	7 43 10 ±	7 45 0	R.
			Last contact	,,	,,	7 48 24		

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation. h m s	G.M.T. of N.A. h m s	Obs.
	1882, Feb. 1	II.	Ec. R. First seen	42-inch telescope	80	9 30 9	9 30 2	R.
			Half brightness	„	„	9 31 22	—	„
			Full brightness	„	„	9 33 22	—	„
	1	III.	Oc. R. First contact	„	„	9 38 51		
			Bisection	„	„	9 43 20	9 49 0	R.
			Last contact	„	„	9 46 50		
	15	I.	Tr. I. First contact	„	„	6 50 45		
			Bisection	„	„	6 55 25	6 52 0	R.
			Last contact	„	„	7 2 48		
	24	II.	Tr. I. Ext. contact	10-foot Equatorial	160	7 8 16		
			Bisection	„	„	7 11 16	7 11 0	R.
			Int. contact	„	„	7 14 45		
	Mar. 3	I.	Tr. E. Int. contact	„	„	7 27 9		
			Bisection	„	„	7 29 23	7 30 0	R.
			Ext. contact	„	„	7 32 38		
	Apr. 3	III.	Tr. I. Ext. contact	Heliometer	200	7 41 57		
			Bisection	„	„	7 49 25	7 45 0	R.
			Int. contact	„	„	7 58 4		
	3	I.	Ec. R. First seen	„	„	8 12 29	8 12 18	R.
			Full brightness	„	„	8 15 30±	—	„

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
(*c*)	1882, Apr. 6	II.	Ec. R. First seen	Heliometer	200	8 57 54	8 57 40	W.
			Half brightness	„	„	8 59 23	—	„
			Full brightness	„	„	9 1 2	—	„
	6	II.	Ec. R. First seen	10-foot Equatorial	160	8 57 36	8 57 40	R.
			Half brightness	„	„	8 59 11	—	„
			Full brightness	„	„	9 0 41	—	„
	1883, Jan. 26	II.	Ec. R. First seen	„	125	9 16 22	9 16 37	R.
			Full brightness	„	„	9 20 12	—	„
	26	I.	Tr. I. Ext. contact	„	„	10 17 17		
			Bisection	„	„	10 20 32	10 21 0	R.
			Internal contact	„	„	10 24 1		
	27	I.	Ec. R. First seen	„	160	10 39 11	10 39 33	F.B.
			Full brightness	„	„	10 41 31	...	„
	Feb. 5	I.	Ec. R. First seen	„	„	7 3 57	7 4 5	R.
			Full brightness	„	„	7 7 27 ±	—	„
(*d*)	5	III.	Tr. I. Ext. contact	„	„	10 49 40		
			Bisection	„	„	10 57 19	10 58 0	R.
			Int. contact	„	„	11 8 42		

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
(*e*)	1883, Feb. 5	III.	Tr. I. Ext. contact	Heliometer	200	10 53 47		
			Bisection	"	"	10 59 31	10 58 0	F.B.
			Int. contact	"	"	11 6 30		
(*f*)	9	III.	Ec. R. First seen	"	"	7 49 49	7 52 23	W.
			Half brightness	"	"	7 55 8	—	"
			Full brightness	"	"	8 1 7	—	"
	9	III.	Ec. R. First seen	10-foot Equatorial	160	7 49 45	7 52 23	R.
			Full brightness	"	"	8 0 9 ±	—	"
	10	I.	Oc. D. Ext. contact	"	"	11 4 25		
			Bisection	"	"	11 7 54 ±	11 9 0	F.B.
			Last contact	"	"	11 9 54		
	12	I.	Ec. R. First seen	"	"	8 59 30	8 59 45	R.
			Full brightness	"	"	9 2 4 ±	—	"
	12	I.	Ec. R. First seen	Heliometer	200	8 59 33	8 59 45	F.B.
	16	III.	Oc. R. Last contact	"	"	7 0 35	7 3 0	W.
	16	III.	Oc. R. Bisection	10-foot Equatorial	125	7 0 20	7 3 0	R.
			Last contact	"	"	7 3 4		
(*g*)	16	III.	Ec. D. Decided diminution	"	"	9 8 14	—	R.
			Last seen	"	"	9 15 18	9 13 20	"

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
	1883, Feb. 16	III.	Ec. D. Last seen	Heliometer	200	9 15 34	9 13 20	F.B.
(*h*)	16	III.	Ec. R. First seen	”	200	11 51 59	11 54 13	W.
			Half brightness	”	80	11 57 1	—	”
			Full brightness	”	80	12 1 45	--	”
	16	III.	Ec. R. First seen	10-foot Equatorial	160	11 51 51	11 54 13	R.
			Full brightness	”	”	11 59 0±	—	”
(*i*)	16	II.	Oc. D. Bisection	Heliometer	80	11 58 16	11 58 0	W.
			Last contact	”	”	12 0 15		
	16	II.	Oc. D. Bisection	10-foot Equatorial	160	11 56 1	11 58 0	R.
			Last contact	”	”	11 59 40		
(*k*)	19	I.	Oc. D. First contact	”	”	7 24 8	7 28 0	R.
			Last contact	”	”	7 29 32		
	23	III.	Oc. D. First contact	”	”	8 3 29		
			Bisection	”	”	8 7 28	8 8 0	F.B.
			Last contact	”	”	8 10 13		
	23	III.	Oc. R. First seen	”	”	10 45 2		
			Bisection	”	”	10 48 32	10 52 0	R.
			Ext. contact	”	”	10 51 31		
	23	III.	Ec. D. Last seen	”	”	13 15 52	13 14 14	R.

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation. h m s	G.M.T. of N.A. h m s	Obs.
	1883, Feb. 26	I.	Oc. D. First contact	10-foot Equatorial	160	9 16 4		
			Bisection	"	"	9 18 54	9 21 0	R.
			Last contact	"	"	9 21 53		
	26	I.	Oc. D. First contact	Heliometer	200	9 19 6		
			Bisection	"	"	9 21 6	9 21 0	F.B.
			Last contact	"	"	9 22 20		
	Mar. 15	I.	Tr. E. Int. contact	10-foot Equatorial	160	7 4 49		
			Bisection	"	"	7 7 58	7 9 0	W.
			Ext. contact	"	"	7 10 18		
	30	I.	Ec. R. First seen	Heliometer	200	9 32 17	9 32 20	F.B.
	30	I.	Ec. R. First seen	10-foot Equatorial	160	9 32 11	9 32 20	R.
(*l*)	31	II.	Ec. R. First seen	Heliometer	200	8 35 28	8 35 14	W.
			Half brightness	"	"	8 38 8	—	"
			Full brightness	"	"	8 40 28	—	"
	31	II.	Ec. R. First seen	10-foot Equatorial	160	8 35 34	8 35 14	F.B.
(*m*)	31	III.	Ec. D. Brightness had dimin.	Heliometer	200	9 9 53	—	W.
			Half brightness	"	"	9 13 53	—	"
			Last seen	"	"	9 18 25	9 16 41	"
	31	III.	Ec. D. Last seen	10-foot Equatorial	160	9 18 48	9 16 41	F.B.

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
(n)	1883, Apr. 4	IV.	Ec. D. Had faded	10-foot Equatorial	160	9 13 21	--	R.
			Last seen	"	"	10 1 28	9 33 54	"
(o)	4	IV.	Ec. D. Last seen	Heliometer	160	10 14 52	9 33 54	F.B.
(p)	4	IV.	Ec. R. First seen	"	"	10 20 51	10 59 48	F.B.
	6	I.	Oc. D. First contact	10-foot Equatorial	160	7 56 9	8 0 0	R.
			Last contact	"	"	8 1 38		
	6	I.	Oc. D. First contact	Heliometer	"	7 56 35	8 0 0	F.B.
			Last contact	"	"	8 0 49		
(q)	6	I.	Ec. R. First seen	10-foot Equatorial	"	11 28 7	11 28 3	R.
	7	III.	Oc. D. First contact	"	"	8 14 14	8 20 0	F.B.
			Bisection	"	"	8 16 58		
			Last contact	"	"	8 20 13		
(r)	7	III.	Oc. R. First contact	"	"	11 6 41	11 11 0	W.
			Last contact	"	"	11 12 40		
	7	III.	Oc. R. First contact	Heliometer	"	11 8 36	11 11 0	F.B.
			Ext. contact	"	"	11 13 20		
	7	II.	Ec. R. First seen	10-foot Equatorial	"	11 11 13	11 10 38	W.
			Half brightness	"	"	11 13 25	--	"
			Full brightness	"	"	11 15 9		"
	7	II.	Ec. R. First seen	Heliometer	"	11 11 24	11 10 38	F.B.

Ref.	Day of Observation.	Satellite.	Phenomenon.	Instrument.	Power.	G.M.T. of Observation.	G.M.T. of N.A.	Obs.
						h m s	h m s	
(s)	1883, Apr. 14	II.	Oc. D. First contact	10-foot Equatorial	125	8 38 25	8 44 0	F.B.
			Last contact	„	„	8 44 54		
	25	III.	Tr. E. Int. contact	„	„	9 53 13	9 56 0	F.B.
			Bisection	„	„	9 56 12		
			Ext. contact	„	„	10 0 42		

Remarks.

(*a*) Bad definition at times, but observation fair. (*b*) Jupiter's limb diffused.
(*c*) Jupiter boiling. Time of first appearance caught as the faintest trace. (*d*) Observation difficult.
(*e*) Images diffused at times. Internal contact fair.
(*f*) Slightly hazy at times, but not sufficient to interfere perceptibly with observations. (*g*) Moonlight, and sky very slightly hazy.
(*h*) Hazy, but faintest trace detected at the time 'First seen.' (*i*) Images bad. Observations unsatisfactory.
(*k*) Observations approximate. (*l*) Images diffused. (*m*) Images better than before.

(*n*) The time $10^h\ 1^m\ 28^s$ G.M.T. was when the satellite was *certainly* last seen by me; but I believe this to be early, as I thought I saw it again several times afterwards, and extending over three or four minutes of time. Observed with Jupiter *in* the field of view (R.)

(*o*) At $9^h\ 58^m$ G.M.T. the satellite had disappeared, when Jupiter was in the field; I continued to watch near the place, and happened to look in when Jupiter was just disappearing from the field, and then caught sight of the satellite, which was still shining distinctly. Gazed until $10^h\ 15^m\ 52^s$, when all trace of it had entirely disappeared. At $10^h\ 13^m\ 52^s$ it was only just visible. The time noted for disappearance is considered good (F.B.) The satellite (J. IV.) must have been about $1^h\ 15^m$ entering the shadow of Jupiter.

(*p*) After having entered the times and notes, &c., in observing book, I went to telescope again, and then saw a very faint trace of the satellite—this was at $11^h\ 20^m\ 51^s$ G.M.T.—but it was certainly brighter than when last seen at disappearance; I consider the time noted "First seen" is not more than two minutes late (F.B.)

(*q*) Images very bad. (*r*) Limbs diffused and tremulous. (*s*) Sky very hazy.

Observers.—W. = Mr. Wickham. R. = Mr. Robinson. F.B. = Mr. Frank Bellamy.

Phenomena of Jupiter's Satellites observed at Mr. E. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1882–3. By J. Gledhill.

Date.	Phenomena.	G.M.T.	Time in *N. Almanac.*	Remarks.
1882.		h m s	h m s	
Nov. 11	I. Tr. I. First contact	9 38 0	9 37 0	Definition poor to-night.
	Inner contact	42 0		
	I. Sh. E. Just off	10 57 0	11 0 0	
	I. Tr. E. Inner contact	11 49 0	11 52 0	
	Outer contact	52 0		
14	II. Tr. I. First contact	11 8 0	11 9 0	Much tremulous motion.
	Inner contact	11 0		
	II. Sh. E. Inner contact	12 15 0	12 15 0	
	Just off	18 0		
27	I. Sh. E. Just off?	9 18 0	9 17 0	Very bad definition.
	I. Tr. E. Inner contact	9 46 0	9 48 0	
	Outer contact	48 0		
1883. Jan. 20	I. Ec. R. First seen	8 43 45	8 44 5	Good observation.
29	III. Tr. I. First contact	7 23 0	7 25 0	
	Bisection	29 0		
	Inner contact	32 0		
Feb. 4	I. Tr. E. Inner contact	8 47 0	8 51 0	
	Bisection	50 0		
	Just off	52 0		
11	I. Tr. E. Just off	10 41 0	10 41 0	Clouds interrupted the observations.
12	I. Ec. R. First seen	8 59 28	8 59 45	
27	*II. Ec. R. First seen	8 55 54	8 56 0	Fairly good observations.
	* Full orb	8 58 0		
Mar. 14	I. Ec. R. First seen	11 11 43	11 11 46	
	Full orb	15 0		
23	I. Ec. R. First seen	7 36 25	7 36 34	
	Full orb	40 0		
31	I. Sh. E. First contact	6 42 0	6 47 0	
	Bisection	44 0		
	Just off	46 0		

* Mr. Crossley was at the telescope during the observations thus marked.

Date.	Phenomena.		G.M.T.	Time in *N. Almanac.*	Remarks.
1883.			h m s	h m s	
Mar. 31	III. Oc. R.	Half out	6 50 0	6 58 0	
		Just off	52 0		
	II. Ec. R.	First seen	8 35 21	8 35 14	
		Full orb	39 0		
	III. Ec. D.	Fading?	9 10 0	9 16 41	
		Certainly fading	9 11 0		
		Fading fast	9 12 0		
		Half gone	9 14 0		
		Easily seen	9 18 0		
		Just gone	9 19 26		
	III. Ec. R.	First seen	12 3 22	12 4 49	
Apr. 6	I. Oc. D.	Outer contact	7 57 30	8 0 0	Good sky.
		Bisection	8 0 0		
		Gone	8 2 0		
	I. Ec. R.	First seen	11 28 0	11 28 3	
		Full orb	11 31 0		Uncertain; planet low.
7	I. Tr. E.	Inner contact	7 26 0	7 29 0	Fair observations.
		Bisection	28 0		
		Outer contact	30 0		
	III. Oc. D.	First contact	8 17 0	8 20 0	Fair observations.
		Bisection	21 0		
		Just gone	23 0		
	I. Sh. E.	Inner contact	8 35 0	8 42 0	Uncertain observations; misty.
		Bisection?	37 0		
		Off?	39 0		
16	II. Sh. E.	Inner contact	8 35 0	8 43 0	Windy; cloudy.
		Just off	8 40 0		
22	I. Ec. R.	First seen	9 48 0	9 48 8	Cloudy.
		Half light	50 0		
		Full	53 0		

Ephemeris for Physical Observations

Greenwich Noon.		Angle of Position of ♃'s Axis.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	A−L.	O−L.	Longitude of ♃'s Central Meridian.	Cor. for Phase.
1883.		°	°	°	°	°	°	°
Sept.	16	13·340	+1·115	+1·346	−9·066	16·876	184·70	+0·36
	21	13·662	1·079	1·326	9·482	16·048	216·29	·39
	26	13·963	1·044	1·306	9·853	15·265	247·95	·42
Oct.	1	14·243	1·010	1·285	10·176	14·531	279·67	·45
	6	14·501	+0·977	+1·265	−10·448	13·849	311·45	+0·47
	11	14·736	·945	1·245	10·664	13·223	343·30	·49
	16	14·947	·915	1·225	10·821	12·655	15·21	·51
	21	15·133	·886	1·205	10·915	12·150	47·19	·52
	26	15·294	·858	1·185	10·943	11·713	79·24	·52
	31	15·428	·832	1·164	10·900	11·347	111·36	·52
Nov.	5	15·535	+0·808	+1·144	−10·783	11·054	143·56	+0·51
	10	15·614	·786	1·124	10·590	10·838	175·83	·49
	15	15·664	·767	1·103	10·317	10·702	208·17	·46
	20	15·685	·750	1·083	9·963	10·647	240·58	·43
	25	15·677	·735	1·063	9·527	10·675	273·05	·39
	30	15·639	·722	1·042	9·008	10·786	305·59	·35
Dec.	5	15·571	+0·712	+1·021	−8·408	10·979	338·20	+0·31
	10	15·475	·705	1·001	7·728	11·251	10·87	·26
	15	15·351	·700	0·980	6·973	11·599	43·58	·21
	20	15·200	·698	·959	6·146	12·019	76·33	·16
	25	15·023	·698	·939	5·254	12·505	109·12	·12
	30	14·824	·700	·918	4·304	13·049	141·93	·08
1884.								
Jan.	4	14·605	+0·704	+0·897	−3·307	13·640	174·76	+0·05
	9	14·370	·710	·876	2·273	14·268	207·59	·02
	14	14·124	·718	·856	1·214	14·922	240·40	+ ·01
	19	13·870	·727	·835	−0·140	15·591	273·19	·00
	24	13·612	·736	·814	+0·935	16·262	305·94	·00
	29	13·356	·747	·793	1·993	16·921	338·64	− ·02

of Jupiter, 1883–84. By A. Marth.

Greenwich Noon.		Diameter Equat.	Polar.	Difference of limbs in A. R.	in Decl.	Defect of illumination. Equat.	in A. R. preced. limb.	d	w
1883.		″	″	s	″	″	s	°	°
Sept.	16	34·14	31·97	2·425	32·09	0·21	0·015	9·07	268·34
	21	34·53	32·33	2·450	32·46	·24	·016	9·49	268·30
	26	34·95	32·72	2·477	32·85	·26	·018	9·86	268·27
Oct.	1	35·39	33·14	2·506	33·28	·28	·019	10·18	268·24
	6	35·86	33·58	2·536	33·72	0·30	0·020	10·45	268·21
	11	36·36	34·04	2·568	34·19	·31	·021	10·66	268·18
	16	36·88	34·53	2·603	34·69	·33	·022	10·82	268·14
	21	37·42	35·04	2·640	35·20	·34	·023	10·92	268·11
	26	37·98	35·56	2·678	35·74	·35	·023	10·95	268·07
	31	38·56	36·11	2·717	36·29	·35	·023	10·91	268·04
Nov.	5	39·16	36·67	2·758	36·85	0·35	0·023	10·79	268·00
	10	39·77	37·23	2·800	37·42	·34	·023	10·59	267·96
	15	40·38	37·81	2·843	38·00	·33	·022	10·32	267·92
	20	40·99	38·38	2·886	38·58	·31	·021	9·97	267·87
	25	41·60	38·95	2·929	39·15	·29	·019	9·53	267·82
	30	42·20	39·51	2·972	39·71	·26	·017	9·01	267·76
Dec.	5	42·78	40·05	3·014	40·25	0·23	0·015	8·41	267·69
	10	43·33	40·57	3·055	40·77	·20	·013	7·73	267·61
	15	43·84	41·05	3·093	41·25	·16	·011	6·98	267·50
	20	44·30	41·48	3·128	41·68	·13	·009	6·15	267·35
	25	44·71	41·87	3·160	42·06	·09	·006	5·26	267·15
	30	45·06	42·20	3·188	42·39	·06	·004	4·31	266·9
1884.									
Jan.	4	45·34	42·46	3·211	42·65	0·04	0·003	3·31	266·4
	9	45·55	42·65	3·229	42·83	·02	·001	2·28	265·2
	14	45·68	42·76	3·241	42·94	·01	·000	1·22	263·1
	19	45·71	42·80	3·248	42·97	following limb		0·18	230·5
	24	45·66	42·76	3·248	42·92	·00	·000	0·94	95·1
	29	45·53	42·64	3·242	42·79	·01	·001	2·00	91·2

Greenwich Noon.		Angle of Position of ♃'s Axis.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	A−L	O−L	Longitude of ♃'s Central Meridian.	Cor. for Phase.
1884.		°	°	°	°	°	°	°
Feb.	3	13·108	+0·758	+0·772	+3·037	17·556	11·27	−0·04
	8	12·872	·768	·751	4·041	18·156	43·83	·08
	13	12·652	·778	·730	4·999	18·710	76·31	·11
	18	12·452	·788	·709	5·902	19·208	108·70	·15
	23	12·277	·797	·688	6·742	19·643	141·00	·20
	28	12·129	·804	·667	7·512	20·011	173·20	·25
Mar.	4	12·010	+0·810	+0·646	+8·208	20·306	205·29	−0·29
	9	11·922	·815	·625	8·825	20·521	237·29	·34
	14	11·867	·818	·604	9·362	20·656	269·18	·38
	19	11·845	·819	·583	9·818	20·711	300·98	·42
	24	11·855	·819	·561	10·194	20·685	332·68	·45
	29	11·898	·817	·540	10·490	20·580	4·29	·48
Apr.	3	11·973	+0·812	+0·519	+10·707	20·397	35·81	−0·50
	8	12·078	·805	·498	10·849	20·137	67·25	·51
	13	12·212	·797	·477	10·918	19·803	98·62	·52
	18	12·374	·787	·455	10·918	19·404	129·92	·52
	23	12·561	·774	·434	10·852	18·941	161·15	·51
	28	12·772	·759	·413	10·723	18·412	192·32	·50
May	3	13·006	+0·743	+0·392	+10·534	17·824	223·45	−0·48
	8	13·259	·725	·370	10·291	17·182	254·53	·46
	13	13·530	·704	·349	9·996	16·488	285·56	·43
	18	13·816	·682	·328	9·653	15·746	316·56	·40
	23	14·117	·658	·307	9·265	14·960	347·52	·37
	28	14·430	·632	·285	8·836	14·133	18·46	·34
June	2	14·754	+0·605	+0·264	+8·369	13·268	49·38	−0·31
	7	15·087	·576	·243	7·868	12·368	80·28	·27
	12	15·426	·545	·222	7·335	11·438	111·17	·23

Greenwich Noon.		Diameter Equat.	Diameter Polar.	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat.	Defect of illumination. in A.R. following limb.	d	w
1884.		"	"	s	"	"	s	°	°
Feb.	3	45·32	42·44	3·231	42·59	0·03	0·002	3·04	90·3
	8	45·04	42·17	3·214	42·32	·05	·004	4·04	89·8
	13	44·68	41·83	3·191	41·98	·08	·006	5·00	89·44
	18	44·26	41·44	3·163	41·58	·12	·008	5·90	89 22
	23	43·79	41·00	3·132	41·13	·15	·010	6·74	89·06
	28	43·27	40·51	3·096	40·64	·19	·013	7·51	88·93
Mar.	4	42·71	39·99	3·058	40·11	0·22	0·015	8·21	88·83
	9	42·12	39·44	3·017	39·56	·25	·017	8·83	88·75
	14	41·52	38·87	2·974	38·99	·28	·019	9·36	88·67
	19	40·90	38·29	2·930	38·41	·30	·021	9·82	88·59
	24	40·27	37·71	2·885	37·82	·32	·022	10·20	88·52
	29	39·65	37·12	2·839	37·23	·33	·023	10·49	88·46
Apr.	3	39·03	36·54	2·794	36·65	0·34	0·024	10·71	88·40
	8	38·42	35·97	2·750	36·08	·34	0·24	10 85	88·34
	13	37·82	35·42	2·706	35·53	·34	·024	10·92	88·28
	18	37·25	34·88	2·663	34·99	·34	·023	10·92	88·21
	23	36·69	34·35	2·621	34·47	·33	·023	10·86	88·15
	28	36 15	33·85	2·581	33·97	·32	·022	10·73	88·09
May	3	35·64	33·37	2·542	33·49	0·30	0·021	10·54	88·02
	8	35·15	32·91	2·505	33·03	·28	·020	10·30	87·95
	13	34·69	32·48	2·469	32·60	·26	·018	10·00	87·88
	18	34·25	32·07	2·435	32·20	·24	·017	9·66	87·81
	23	33·84	31·69	2·403	31·82	·22	·015	9·27	87·73
	28	33·46	31·33	2·372	31·46	·20	·014	8·84	87·64
June	2	33·10	30·99	2·344	31·13	0·18	0·012	8·38	87·55
	7	32·77	30·68	2·318	30·83	·15	·011	7·88	87·44
	12	32·47	30·40	2·292	30 55	·13	·009	7·34	87·33

The angle $\Lambda - L$ is the difference of the Jovicentric longitudes of the Sun and the Earth, reckoned in the plane of *Jupiter's* equator, $O - L$ the difference of longitudes of *Jupiter's* vernal equinoctial point O and of the point of his equator which is in opposition to the Earth, or $L + 180° - O$ is the Jovicentric longitude of the Earth reckoned from O.

The assumed daily rate of rotation, on which the "Longitude of ♃'s Central Meridian" depends, is the same as has been adopted in the ephemerides of the last two apparitions—namely, 870°·42, the corresponding period being $9^{h}\ 55^{m}\ 34^{s}\cdot47$. Even if it should be found that, since last seen, the great reddish spot has entirely faded away, its place ought to be watched specially, and for the purpose it seems desirable not to make any alteration for the present. In the column "Longitude of ♃'s Central Meridian" the successive values differ, for an interval of five days, by twelve rotations and some thirty degrees, so that, for instance, the first difference is 4351°·59 and the last 4350°·89, which must be borne in mind in interpolating. If the "Corr. for Phase" is added to the "Longitude of ♃'s Central Meridian," or of the meridian directed to the Earth, the longitude of the meridian is found which bisects the illuminated disk of the planet.

The assumed value of *Jupiter's* equatorial diameter is 37″·60 at the distance 5·20273. The assumed proportion of the polar axis to the equatorial diameter is 0·9363. The defect of illumination of the apparent polar diameter is insensible, that of the difference of limbs in declination is 0″·02 from October 6 to November 30 and 0″·01 for the other dates, except from December 25 to February 13, when it is insensible. The last columns give the values of the auxiliary angles d and w required in the computations for defect of illumination, as explained in vol. xl. p. 490 ff.

The following is a list of the Greenwich mean times, when the assumed First Meridian of *Jupiter* passes the middle of the illuminated disk:—

1883.	h	m	1883.	h	m	1883.	h	m	1883.	h	m
Sept. 15	18	53·8	Sept. 20	18	1·5	Sept. 25	17	9·1	Sept. 30	16	16·5
16	4	49·4	21	3	57·1	26	3	4·7	Oct. 1	2	12·2
	14	45·1		13	52·8		13	0·3		12	7·8
17	0	40·7		23	48·4		22	55·9		22	3·4
	10	36·4	22	9	44·0	27	8	51·6	2	7	59·0
	20	32·0		19	39·7		18	47·2		17	54·6
18	6	27·7	23	5	35·3	28	4	42·8	3	3	50·3
	16	23·3		15	30·9		14	38·4		13	45·9
19	2	18·9	24	1	26·5	29	0	34·1		23	41·5
	12	14·6		11	22·2		10	29·7	4	9	37·1
	22	10·2		21	17·8		20	25·3		19	32·7
20	8	5·9	25	7	13·4	30	6	20·9	5	5	28·3

1883.		h	m	1883.		h	m	1883.		h	m	1883.		h	m
Oct.	5	15	23·9	Oct.	22	4	27·8	Nov.	7	17	30·5	Nov.	24	6	32·1
	6	1	19·5			14	23·4		8	3	26·1			16	27·7
		11	15·2		23	0	19·0			13	21·7		25	2	23·2
		21	10·8			10	14·6			23	17·2			12	18·7
	7	7	6·4			20	10·2		9	9	12·6			22	14·2
		17	2·0		24	6	5·7			19	8·3		26	8	9·8
	8	2	57·6			16	1·3		10	5	3·9			18	5·3
		12	53·2		25	1	56·9			14	59·4		27	4	0·8
		22	48·8			11	52·5		11	0	55·0			13	56·3
	9	8	44·4			21	48·0			10	50·5			23	51·8
		18	40·0		26	7	43·6			20	46·1		28	9	47·4
	10	4	35·6			17	39·2		12	6	41·6			19	42·9
		14	31·2		27	3	34·8			16	37·2		29	5	38·4
	11	0	26·8			13	30·3		13	2	32·7			15	33·9
		10	22·4			23	25·9			12	28·2		30	1	29·4
		20	18·0		28	9	21·5			22	23·8			11	24·9
	12	6	13·6			19	17·1		14	8	19·3			21	20·4
		16	9·2		29	5	12·6			18	14·9	Dec.	1	7	16·0
	13	2	4·8			15	8·2		15	4	10·4			17	11·5
		12	0·4		30	1	3·8			14	6·0		2	3	7·0
		21	56·0			10	59·3		16	0	1·5			13	2·5
	14	7	51·6			20	54·9			9	57·0			22	58·0
		17	47·2		31	6	50·5			19	52·6		3	8	53·5
	15	3	42·8			16	46·0		17	5	48·1			18	49·0
		13	38·4	Nov.	1	2	41·6			15	43·6		4	4	44·5
		23	34·0			12	37·2		18	1	39·2			14	40·0
	16	9	29·6			22	32·7			11	34·7		5	0	35·5
		19	25·2		2	8	28·3			21	30·2			10	31·0
	17	5	20·8			18	23·9		19	7	25·8			20	26·6
		15	16·4		3	4	19·4			17	21·3		6	6	22·1
	18	1	11·9			14	15·0		20	3	16·8			16	17·6
		11	7·5		4	0	10·5			13	12·4		7	2	13·1
		21	3·1			10	6·1			23	7·9			12	8·6
	19	6	58·7			20	1·7		21	9	3·4			22	4·1
		16	54·3		5	5	57·2			18	59·0		8	7	59·6
	20	2	49·9			15	52·8		22	4	54·5			17	55·1
		12	45·5		6	1	48·3			14	50·0		9	3	50·6
		22	41·1			11	43·9		23	0	45·6			13	46·1
	21	8	36·7			21	39·4			10	41·1			23	41·6
		18	32·2		7	7	35·0			20	36·6		10	9	37·1

1883.		h	m	1883.		h	m	1884.		h	m	1884.		h	m
Dec.	10	19	32·6	Dec.	27	8	32·2	Jan.	12	11	35·9	Jan.	29	0	35·4
	11	5	28·1			18	27·7			21	31·4			10	30·9
		15	23·6		28	4	23·2		13	7	26·9			20	26·4
	12	1	19·1			14	18·6			17	22·3		30	6	21·9
		11	14·6		29	0	14·1		14	3	17·8			16	17·4
		21	10·1			10	9·6			13	13·3		31	2	12·9
	13	7	5·6			20	5·1			23	8·8			12	8·4
		17	1·1		30	6	0·6		15	9	4·3			22	3·9
	14	2	56·6			15	56·0			18	59·7	Feb.	1	7	59·4
		12	52·1		31	1	51·5		16	4	55·2			17	54·9
		22	47·6			11	47·0			14	50·7		2	3	50·4
	15	8	43·1			21	42·5		17	0	46·2			13	45·9
		18	38·5	1884.						10	41·7			23	41·4
	16	4	34·0	Jan.	1	7	38·0			20	37·1		3	9	36·9
		14	29·5			17	33·4		18	6	32·6			19	32·4
	17	0	25·0		2	3	28·9			16	28·1		4	5	28·0
		10	20·5			13	24·4		19	2	23·6			15	23·5
		20	16·0			23	19·9			12	19·1		5	1	19·0
	18	6	11·5		3	9	15·4			22	14·6			11	14·5
		16	7·0			19	10·8		20	8	10·0			21	10·0
	19	2	2·5		4	5	6·3			18	5·5		6	7	5·5
		12	58·0			15	1·8		21	4	1·0			17	1·1
		21	53·5		5	0	57·3			13	56·5		7	2	56·6
	20	7	49·0			10	52·8			23	52·0			12	52·1
		17	44·4			20	48·2		22	9	47·5			22	47·6
	21	3	39·9		6	6	43·7			19	43·0		8	8	13·1
		13	35·4			16	39·2		23	5	38·4			18	38·7
		23	30·9		7	2	34·7			15	33·9		9	4	34·2
	22	9	26·4			12	30·2		24	1	29·4			14	29·7
		19	21·9			22	25·6			11	24·9		10	0	25·2
	23	5	17·4		8	8	21·1			21	20·4			10	20·8
		15	12·8			18	16·6		25	7	15·9			20	16·3
	24	1	8·3		9	4	12·1			17	11·4		11	6	11·8
		11	3·8			14	7·5		26	3	6·9			16	7·3
		20	59·3		10	0	3·0			13	2·4		12	2	2·9
	25	6	54·8			9	58·5			22	57·9			11	58·4
		16	50·3			19	54·0		27	8	53·4			21	53·9
	26	2	45·7		11	5	49·5			18	48·9		13	7	49·5
		12	41·2			15	44·9		28	4	44·4			17	45·0
		22	36·7		12	1	40·4			14	39·9		14	3	40·5

1884.	h	m	1884.	h	m	1884.	h	m	1884.	h	m
Feb. 14	13	36·1	Mar. 2	2	38·5	Mar. 18	15	42·7	Apr. 4	4	48·6
	23	31·6		12	34·1	19	1	38·3		14	44·2
15	9	27·2		22	29·7		11	34·0	5	0	39·9
	19	22·7	3	8	25·3		21	29·4		10	35·6
16	5	18·2		18	20·8	20	7	25·2		20	31·2
	15	13·8	4	4	16·4		17	20·9	6	6	26·9
17	1	9·3		14	12·0	21	3	16·5		16	22·6
	11	4·9	5	0	7·6		13	12·1	7	2	18·2
	21	0·4		10	3·2		23	7·8		12	13·9
18	6	56·0		19	58·8	22	9	3·4		22	9·6
	16	51·5	6	5	54·4		18	59·0	8	8	5·2
19	2	47·1		15	50·0	23	4	54·7		18	0·9
	12	42·6	7	1	45·6		14	50·3	9	3	56·6
	22	38·2		11	41·2	24	0	45·9		13	52·3
20	8	33·7		21	36·8		10	41·6		23	47·9
	18	29·3	8	7	32·4		20	37·2	10	9	43·6
21	4	24·8		17	28·0	25	6	32·9		19	39·3
	14	20·4	9	3	23·6		16	28·5	11	5	35·0
22	0	16·0		13	19·2	26	2	24·2		15	30·6
	10	11·5		23	14·8		12	19·8	12	1	26·3
	20	7·1	10	9	10·4		22	15·4		11	22·0
23	6	2·6		19	6·0	27	8	11·1		21	17·7
	15	58·2	11	5	1·6		18	6·7	13	7	13·4
24	1	53·8		14	57·2	28	4	2·4		17	9·0
	11	49·3	12	0	52·8		13	58·0	14	3	4·7
	21	44·9		10	48·4		23	53·7		13	0·4
25	7	40·4		20	44·1	29	9	49·3		22	56·1
	17	36·0	13	6	39·7		19	45·0	15	8	51·8
26	3	31·6		16	35·3	30	5	40·6		18	47·4
	13	27·2	14	2	30·9		15	36·3	16	4	43·1
	23	22·7		12	26·5	31	1	32·0		14	38·8
27	9	18·3		22	22·1		11	27·6	17	0	34·5
	19	13·9	15	8	17·7		21	23·3		10	30·2
28	5	9·5		18	13·4	Apr. 1	7	18·9		20	25·9
	15	5·0	16	4	9·0		17	14·6	18	6	21·6
29	1	0·6		14	4·6	2	3	10·3		16	17·3
	10	56·2	17	0	0·2		13	5·9	19	2	12·9
	20	51·8		9	55·8		23	1·6		12	8·6
Mar. 1	6	47·3		19	51·5	3	8	57·2		22	4·3
	16	42·9	18	5	47·1		18	52·9	20	8	0·0

1884.	h	m	1884.	h	m	1884.	h	m	1884.	h	m
Apr. 20	17	55·7	May 3	23	38·2	May 17	5	21·1	May 30	11	4·4
21	3	51·4	4	9	33·9		15	16·8		21	0·1
	13	47·1		19	29·6	18	1	12·5	31	6	55·9
	23	42·8	5	5	25·3		11	8·3		16	51·6
22	9	38·5		15	21·0		21	4·0	June 1	2	47·3
	19	34·2	6	1	16·7	19	6	59·7		12	43·1
23	5	29·9		11	12·4		16	55·4		22	38·8
	15	25·6		21	8·1	20	2	51·2	2	8	34·5
24	1	21·3	7	7	3·9		12	46·9		18	30·3
	11	17·0		16	59·6		22	42·6	3	4	26·0
	21	12·7	8	2	55·3	21	8	38·4		14	21·7
25	7	8·4		12	51·0		18	34·1	4	0	17·5
	17	4·1		22	46·7	22	4	29·8		10	13·2
26	2	59·8	9	8	42·4		14	25·5		20	8·9
	12	55·5		18	38·1	23	0	21·3	5	6	4·7
	22	51·2	10	4	33·9		10	17·0		16	0·4
27	8	46·9		14	29·6		20	12·7	6	1	56·1
	18	42·6	11	0	25·3	24	6	8·4		11	51·9
28	4	38·3		10	21·0		16	4·2		21	47·6
	14	34·0		20	16·7	25	1	59·9	7	7	43·3
29	0	29·7	12	6	12·5		11	55·6		17	39·1
	10	25·4		16	8·2		21	51·4	8	3	34·8
	20	21·1	13	2	3·9	26	7	47·1		13	30·5
30	6	16·8		11	59·6		17	42·8		23	26·3
	16	12·5		21	55·3	27	3	38·5	9	9	22·0
May 1	2	8·2	14	7	51·0		13	34·3		19	17·7
	12	3·9		17	46·8		23	30·0	10	5	13·5
	21	59·6	15	3	42·5	28	9	25·7		15	9·2
2	7	55·3		13	38·2		19	21·5	11	1	4·9
	17	51·0		23	33·9	29	5	17·2		11	0·7
3	3	46·7	16	9	29·6		15	12·9		20	56·4
	13	42·5		19	25·4	30	1	8·7	12	6	52·1

According to observations made last April by Mr. Denning, the centre of the very much faded reddish spot followed the First Meridian of the Ephemeris about $1^h\ 34^m$. In case the slackening of the motion has continued, the spot or its place will be near the centre of the disk, when observations become again feasible, about two hours after the times in the foregoing list.

Ephemerides of the Satellites of Saturn, 1883–84.
By A. Marth.

The following ephemerides of the five inner satellites are founded upon the same elements as those for the preceding apparition, which were published in the last volume of the *Monthly Notices*. The five satellites deviate so little from the plane of the ring, that it will be most suitable to treat their deviations as latitudes above this plane, the ascending node N and inclination J of which in reference to the plane of the Earth's equator being here assumed :—

1883, Aug. 27	N = 126°·4833	J = 7°·0119
Sept. 26	·4852	·0116
Oct. 26	·4880	·0115
Nov. 25	·4921	·0113
Dec. 25	·4965	·0110
1884, Jan. 24	·4997	·0105
Feb. 23	·5015	·0101
Mar. 24	126·5032	7·0099

the longitudes N being reckoned from the point of the true equinox.

The assumed longitudes of the satellites in their orbits (i.e. their longitudes from the ascending node added to the right ascension N of the ascending node), referring to the time when the light arrives at the distance, the logarithm of which is 0·950, are the following :—

0^h Gr.	Mimas.	Enceladus.	Tethys.	Dione.	Rhea.
1883, Aug. 27	129°·657	185°·881	202°·304	82°·635	269°·080
Sept. 26	69·389	147·838	163·249	68·687	139·785
Oct. 26	9·122	109·795	124·194	54·739	10·490
Nov. 25	308·856	71·752	85·138	40·791	241·194
Dec. 25	248·590	33·708	46·083	26·843	111·899
1884, Jan. 24	188·326	355·665	7·027	12·894	342·603
Feb. 23	128·063	317·622	327·972	358·946	213·308
Mar. 24	67·801	279·579	288·917	344·998	84·013

In the following tables P denotes the position-angle of the minor axis of the ring, L + 180° the planetocentric longitude of the Earth referred to the plane of the ring; Λ + 180° that of the Sun, or Λ − L the difference between the two. The apparent equatorial diameter of the ball and the diameter of the outer rim of the ring depend on Bessel's determinations. The assumed proportion of the polar axis of the ball to the equatorial diameter is 0·900.

In the tables for the satellites a and b are the semi-axes of the apparent orbits, their values depending on Bessel's determination of the major axis of the orbit of *Titan*, and $l-\mathrm{L}$ are the longitudes of the satellites in their orbits reckoned from the points which are in superior conjunction with the planet's centre, or are in opposition to the Earth in longitude. By adding to $l-\mathrm{L}$ the value of L from the first table, the longitudes l are found.

The values of P, a, b and $l-\mathrm{L}$ are to be interpolated for the times for which the apparent positions of the satellites are required, and the rectangular coordinates x and y, reckoned parallel to the axes of the ring and expressed in seconds of arc, or if polar-coordinates are wanted, the position-angles p and distances s of the satellites in reference to the centre of the planet are then found by

$$s \sin(p-\mathrm{P}) = x = a \sin(l-\mathrm{L}).$$
$$s \cos(p-\mathrm{P}) = y = b \cos(l-\mathrm{L}).$$

0^{h} Gr.	P	L	Latitude of Earth above plane of ring.	Latitude of Sun above plane of ring.	A−L
1882.	°	°	°	°	°
Aug. 27	355·912	69·759	−25·947	−25·267	−7·003
Sept. 1	355·886	69·991	25·951	25·297	7·034
6	355·866	70·176	25·951	25·326	7·017
11	355·851	70·312	25·948	25·355	6·952
16	355·842	70·399	25·941	25·384	6·837
21	355·838	70·436	25·931	25·412	6·672
26	355·840	70·422	25·919	25·440	6·456
Oct. 1	355·848	70·357	−25·904	−25·468	−6·188
6	355·861	70·242	25·886	25·496	5·871
11	355·879	70·079	25·865	25·524	5·505
16	355·903	69·869	25·841	25·551	5·093
21	355·932	69·614	25·815	25·578	4·635
26	355·965	69·319	25·788	25·605	4·137
31	356·003	68·985	25·758	25·631	3·600
Nov. 5	356·045	68·618	−25·727	−25·657	−3·029
10	356·091	68·222	25·694	25·683	2·430
15	356·139	67·803	25·659	25·709	1·807
20	356·189	67·366	25·623	25·734	1·167
25	356·240	66·919	25·587	25·759	−0·516
30	356·293	66·466	25·551	25·784	+0·141

0^h Gr.		P	L	Latitude of Earth above plane of ring.	Latitude of Sun above plane of ring.	A−L
1882.		°	°	°	°	°
Dec.	5	356.345	66.015	−25.515	−25.808	+0.796
	10	356.396	65.573	25.481	25.832	1.442
	15	356.446	65.145	25.450	25.856	2.074
	20	356.494	64.737	25.421	25.880	2.685
	25	356.538	64.356	25.394	25.903	3.270
	30	356.579	64.007	25.372	25.926	3.824
1884.						
Jan.	4	356.616	63.695	−25.355	−25.949	+4.342
	9	356.648	63.423	25.343	25.971	4.818
	14	356.675	63.195	25.336	25.993	5.251
	19	356.696	63.014	25.335	26.015	5.637
	24	356.711	62.881	25.341	26.037	5.975
	29	356.721	62.798	25.354	26.058	6.263
Feb.	3	356.724	62.767	−25.372	−26.079	+6.499
	8	356.721	62.788	25.397	26.100	6.683
	13	356.712	62.861	25.429	26.120	6.815
	18	356.697	62.985	25.466	26.140	6.897
	23	356.676	63.160	25.509	26.160	6.928
	28	356.649	63.384	25.557	26.180	6.910
Mar.	4	356.616	63.655	−25.609	−26.199	+6.844
	9	356.578	63.972	25.666	26.218	6.733
	14	356.535	64.332	25.726	26.237	6.578
	19	356.487	64.734	25.789	26.256	6.382
	24	356.435	65.175	−25.854	−26.274	+6.147

0^h Gr.		Diameter of Ball. Equat.	Phase prec. l.	Polar	Axis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	l_1-L	Diff.
1883.		″	″	″	″	′	″	″	°	°
Aug.	27	17.82	0.067	16.40	41.08	17.98	28.02	−12.26	59.42	1909.90
Sept.	1	17.98	.068	16.55	41.46	18.14	28.28	12.38	169.32	1909.95
	6	18.15	.068	16.70	41.84	18.31	28.54	12.49	279.27	1910.00
	11	18.32	.067	16.85	42.23	18.48	28.81	12.60	29.27	.05
	16	18.49	.066	17.01	42.62	18.64	29.07	12.72	139.32	.10
	21	18.66	.063	17.16	43.01	18.81	29.34	12.83	249.42	.15
	26	18.82	.060	17.32	43.39	18.97	29.60	12.94	359.57	.18

0^h Gr.	Diameter of Ball. Equat.	Phase prec. l.	Polar	Axis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	$l_1 - L$	Diff.
1883.	″	″	″	″	″	″	″	°	°
Oct. 1	18·99	0·055	17·47	43·77	19·12	29·86	−13·04	109·75	1910·22
6	19·15	·050	17·61	44·14	19·27	30·11	13·14	219·97	·27
11	19·30	·044	17·75	44·49	19·41	30·35	13·24	330·24	·30
16	19·44	·038	17·89	44·82	19·54	30·58	13·33	80·54	·34
21	19·58	·032	18·01	45·13	19·66	30·79	13·42	190·88	·36
26	19·70	·026	18·12	45·42	19·76	30·98	13·48	301·24	·39
31	19·81	·020	18·22	45·67	19·85	31·15	13·54	51·63	·41
Nov. 5	19·91	·014	18·31	45·89	19·92	31·30	−13·59	162·04	1910·42
10	19·99	·009	18·38	46·07	19·98	31·43	13·63	272·46	·43
15	20·05	·005	18·44	46·22	20·01	31·53	13·65	22·89	·43
20	20·09	·002	18·47	46·32	20·03	31·59	13·66	133·32	·43
25	20·12	·000	18·50	46·37	20·03	31·63	13·66	243·75	·41
30	20·12	foll. l.	18·50	46·38	20·00	31·64	13·65	354·16	·39
Dec. 5	20·10	·001	18·48	46·34	19·96	31·61	−13·62	104·55	1910·37
10	20·07	·003	18·45	46·26	19·90	31·56	13·58	214·92	·34
15	20·02	·007	18·40	46·14	19·83	31·47	13·52	325·26	·30
20	19·94	·011	18·33	45·98	19·73	31·36	13·46	75·56	·25
25	19·85	·016	18·25	45·77	19·63	31·22	13·39	185·81	·21
30	19·75	·022	18·15	45·53	19·51	31·06	13·31	296·02	·16
1884. Jan. 4	19·63	·029	18·04	45·25	19·38	30·87	−13·22	46·18	1910·10
9	19·50	·035	17·92	44·95	19·24	30·66	13·12	156·28	1910·05
14	19·36	·041	17·79	44·62	19·10	30·44	13·02	266·33	1909·99
19	19·21	·047	17·65	44·27	18·95	30·20	12·92	16·32	·94
24	19·05	·052	17·51	43·91	18·79	29·95	12·82	126·26	·87
29	18·88	·056	17·36	43·53	18·64	29·69	12·71	236·13	·82
Feb. 3	18·72	·060	17·20	43·14	18·49	29·43	−12·61	345·95	1909·76
8	18·55	·063	17·05	42·75	18·34	29·16	12·51	95·71	·71
13	18·38	·065	16·89	42·36	18·19	28·90	12·41	205·42	·65
18	18·21	·065	16·74	41·97	18·05	28·63	12·31	315·07	·60
23	18·04	·065	16·58	41·58	17·91	28·37	12·22	64·67	·55
28	17·87	·064	16·43	41·20	17·78	28·11	12·13	174·22	·50
Mar. 4	17·71	·063	16·29	40·83	17·65	27·85	−12·04	283·72	1909·46
9	17·56	·061	16·15	40·48	17·53	27·61	11·96	33·18	·42
14	17·41	·057	16·01	40·14	17·42	27·38	11·88	142·60	·39
19	17·27	·053	15·88	39·81	17·32	27·15	11·81	251·99	·35
24	17·13	0·049	15·76	39·50	17·22	26·94	−11·75	1·34	

0^h Gr.	Enceladus. a_2	b_2	l_2-L	Diff.	Tethys. a_3	b_3	l_3-L	Diff.
1883.	"	"	°	°	"	"	°	°
Aug. 27	35·95	−15·73	115·77	1313·56	44·50	−19·47	132·31	953·34
Sept. 1	36·28	15·88	349·33	·61	44·91	19·65	5·65	·40
6	36·61	16·02	222·94	·65	45·32	19·83	239·05	·45
11	36·95	16·17	96·59	·70	45·74	20·02	112·50	·49
16	37·29	16·31	330·29	·74	46·17	20·20	345·99	·54
21	37·63	16·46	204·03	·79	46·59	20·37	219·53	·59
26	37·97	16·60	77·82	·84	47·01	20·55	93·12	·64
Oct. 1	38·30	−16·73	311·66	1313·88	47·42	−20·71	326·76	953·68
6	38·62	16·86	185·54	·93	47·81	20·87	200·44	·73
11	38·93	16·98	59·47	1313·96	48·20	21·03	74·17	·77
16	39·22	17·10	293·43	1314·00	48·56	21·17	307·94	·81
21	39·50	17·20	167·43	·04	48·89	21·29	181·75	·85
26	39·75	17·29	41·47	·06	49·20	21·40	55·60	·87
31	39·97	17·37	275·53	·08	49·48	21·50	289·47	·90
Nov. 5	40·16	−17·43	149·61	1314·11	49·71	−21·58	163·37	953·92
10	40·32	17·48	23·72	·12	49·91	21·64	37·29	·94
15	40·44	17·51	257·84	·12	50·07	21·68	271·23	·94
20	40·53	17·53	131·96	·12	50·17	21·70	145·17	·95
25	40·58	17·53	6·08	·11	50·23	21·69	19·12	·95
30	40·59	17·51	240·19	·11	50·24	21·67	253·07	·93
Dec. 5	40·56	−17·47	114·30	1314·08	50·20	−21·63	127·00	953·92
10	40·49	17·42	348·38	·05	50·12	21·56	0·92	·90
15	40·38	17·35	222·43	1314·02	49·98	21·48	234·82	·86
20	40·23	17·27	96·45	1313·99	49·80	21·38	108·68	·83
25	40·05	17·18	330·44	·94	49·58	21·26	342·51	·79
30	39·84	17·07	204·38	·90	49·32	21·13	216·30	·75
1884. Jan. 4	39·60	−16·96	78·28	1313·85	49·02	−20·99	90·05	953·70
9	39·34	16·84	312·13	·79	48·69	20·84	323·75	·66
14	39·05	16·71	185·92	·74	48·34	20·68	197·41	·60
19	38·74	16·58	59·66	·68	47·96	20·52	71·01	·54
24	38·42	16·45	293·34	·63	47·57	20·36	304·55	·49
29	38·09	16·31	166·97	·58	47·16	20·19	178·04	·44

		Enceladus.				Tethys.			
0^h Gr.	a_2	b_2	l_2-L	Diff.	a_3	b_3	l_3-L	Diff.
1883.	″	″	°	°	″	″	°	°
Feb. 3	37·75	−16·18	40·55	1313·52	46·74	−20·03	51·48	953·38
8	37·41	16·05	274·07	·46	46·31	19·86	284·86	·33
13	37·07	15·92	147·53	·41	45·89	19·70	158·19	·28
18	36·73	15·79	20·94	·36	45·47	19·55	31·47	·22
23	36·39	15·67	254·30	·31	45·05	19·40	264·69	·18
28	36·06	15·56	127·61	·26	44·64	19·26	137·87	·13
Mar. 4	35·73	−15·45	0·87	1313·22	44·24	−19·12	11·00	953·09
9	35·42	15·34	234·09	·18	43·85	18·99	244·09	·04
14	35·12	15·24	107·27	·14	43·48	18·87	117·13	953·09
19	34·83	15·15	340·41	1313·11	43·12	18·76	350·13	952·97
24	34·56	−15·07	213·52		42·78	−18·66	223·10	

		Dione.				Rhea.		
0^h Gr.	a_4	b_4	l_4-L	Diff.	a_5	b_5	l_5-L	Diff.
1883.	″	″	°	°	″	″	°	°
Aug. 27	57·00	−24·94	12·71	657·51	79·60	−34·83	199·22	398·26
Sept. 1	57·52	25·17	310·22	·55	80·33	35·15	237·48	·30
6	58·05	25·40	247·77	·60	81·07	35·48	275·78	·36
11	58·59	25·64	185·37	·65	81·82	35·80	314·14	·40
16	59·13	25·87	123·02	·70	82·57	36·12	352·54	·45
21	59·67	26·09	60·72	·75	83·33	36·44	30·99	·50
26	60·20	26·31	358·47	·80	84·07	36·75	69·49	·55
Oct. 1	60·73	−26·53	296·27	657·84	84·81	−37·05	108·04	398·59
6	61·24	26·73	234·11	·89	85·52	37·34	146·63	·65
11	61·73	26·93	172·00	·93	86·20	37·61	185·28	·69
16	62·19	27·11	109·93	657·98	86·85	37·86	223·97	·73
21	62·62	27·27	47·91	658·01	87·45	38·08	262·70	·77
26	63·02	27·41	345·92	·04	88·00	38·28	301·47	·81
31	63·37	27·54	283·96	·07	88·49	38·46	340·28	·83
Nov. 5	63·67	−27·64	222·03	658·10	88·92	−38·60	19·11	398·87
10	63·92	27·71	160·13	·11	89·27	38·70	57·98	·88
15	64·12	27·76	98·24	·13	89·55	38·77	96·86	·89
20	64·26	27·79	36·37	·13	89·74	38·81	135·75	·90
25	64·34	27·79	334·50	·13	89·84	38·80	174·65	·91
30	64·35	27·76	272·63	·12	89·86	38·76	213·56	·90

		Dione.					*Rhea.*		
0h Gr.		a_4	b_4	l_4-L	Diff.	a_5	b_5	l_5-L	Diff.
1883.		″	″	°	°	″	″	°	°
Dec.	5	64·30	−27·70	210·75	658·10	89·79	−38·68	252·46	398·88
	10	64·19	27·62	148·85	·09	89·64	38·56	291·34	·87
	15	64·02	27·51	86·94	·06	89·40	38·42	330·21	·85
	20	63·79	27·38	25·00	658·03	89·08	38·24	9·06	·81
	25	63·50	27·23	323·03	657·99	88·68	38·03	47·87	·78
	30	63·17	27·07	261·02	·95	88·21	37·80	96·65	·74
1884.									
Jan.	4	62·79	−26·89	198·97	657·91	87·68	−37·55	125·39	398·70
	9	62·37	26·69	136·88	·85	87·09	37·28	164·09	·65
	14	61·91	26·49	74·73	·81	86·46	37·00	202·74	·60
	19	61·43	26·28	12·54	·75	85·78	36·71	241·34	·55
	24	60·92	26·07	310·29	·70	85·07	36·41	279·89	·50
	29	60·40	25·86	247·99	·65	84·34	36·11	318·39	·45
Feb.	3	59·86	−25·65	185·64	657·60	83·59	−35·82	356·84	398·39
	8	59·32	25·44	123·24	·54	82·83	35·53	35·23	·34
	13	58·77	25·24	60·78	·49	82·07	35·24	73·57	·29
	18	58·23	25·04	358·27	·43	81·32	34·96	111·86	·24
	23	57·69	24·85	295·70	·39	80·57	34·70	150·10	·19
	28	57·17	24·66	233·09	·35	79·83	34·44	188·29	·14
Mar.	4	56·66	−24·49	170·44	657·30	79·12	−34·20	226·43	398·10
	9	56·16	24·32	107·74	·25	78·43	33·97	264·53	·05
	14	55·68	24·17	44·99	·21	77·76	33·75	302·58	398·01
	19	55·23	24·03	342·20	·18	77·13	33·55	340·59	397·98
	24	54·80	−23·90	279·38		76·52	−33·37	18·57	

Approximate Greenwich Mean Times of conjunctions of the satellites with the centre of *Saturn*:

"*n*" inferior conjunction with centre, or satellite exactly in the direction of the minor axis of the ring, north, moving from the following to the preceding side.

"*s*" superior conjunction, or satellite south, moving from the preceding to the following side.

1883.	h			1883.	h			1883.	h		
Aug. 26	7·3	Te.	s.	28	4·7	Te.	s.		15·4	Di.	s.
	18·2	Rh.	n.		6·5	Di.	n.	30	2·0	Te.	s.
	21·7	Di.	s.	29	0·5	Rh.	s.	31	0·2	Di.	n.
27	6·0	Te.	n.		3·3	Te.	n.		0·6	Te.	n.

1883.		h		
Aug.	31	6·7	Rh.	n.
		23·3	Te.	s.
Sept.	1	9·1	Di.	s.
		21·9	Te.	n.
	2	12·9	Rh.	s.
		17·9	Di.	n.
		20·6	Te.	s.
	3	19·3	Te.	n.
	4	2·8	Di.	s.
		17·9	Te.	s.
		19·2	Rh.	n.
	5	11·6	Di.	n.
		16·6	Te.	n.
	6	12·5	En.	s.
		15·2	Te.	s.
		16·4	Mi.	n.
		20·5	Di.	s.
	7	1·4	Rh.	s.
		13·9	Te.	n.
		15·0	Mi.	n.
		21·4	En.	s.
	8	5·3	Di.	n.
		12·5	Te.	s.
		13·6	Mi.	n.
		13·8	En.	n.
	9	7·6	Rh.	n.
		11·2	Te.	n.
		12·2	Mi.	n.
		14·2	Di.	s.
		22·7	En.	n.
	10	9·8	Te.	s.
		10·8	Mi.	n.
		15·2	En.	s.
		23·0	Di.	n.
	11	7·6	En.	n.
		8·5	Te.	n.
		13·8	Rh.	s.
		20·8	Mi.	s.
	12	7·1	Te.	s.
		7·9	Di.	s.

1883.		h		
Sept.	12	16·5	En.	n.
		19·4	Mi.	s.
	13	5·8	Te.	n.
		8·9	En.	s.
		16·7	Di.	n.
		18·0	Mi.	s.
		20·0	Rh.	n.
	14	4·5	Te.	s.
		16·6	Mi.	s.
		17·8	En.	s.
	15	1·5	Di.	s.
		3·1	Te.	n.
		10·3	En.	n.
		15·2	Mi.	s.
	16	1·8	Te.	s.
		2·2	Rh.	s.
		10·4	Di.	n.
		13·8	Mi.	s.
		19·2	En.	n.
	17	0·4	Te.	n.
		11·6	En.	s.
		12·5	Mi.	s.
		19·2	Di.	s.
		23·1	Te.	s.
	18	8·5	Rh.	n.
		11·1	Mi.	s.
		20·5	En.	s.
		21·7	Te.	n.
	19	4·1	Di.	n.
		12·9	En.	n.
		20·4	Te.	s.
		21·0	Mi.	n.
	20	12·9	Di.	s.
		14·7	Rh.	s.
		19·0	Te.	n.
	21	17·7	Te.	s.
		21·7	Di.	n.
	22	16·3	Te.	n.
		16·9	Mi.	n.
		20·9	Rh.	n.

1883.		h		
Sept.	22	23·1	En.	s.
	23	6·6	Di.	s.
		15·0	Te.	s.
		15·5	Mi.	n.
		15·6	En.	n.
	24	8·0	En.	s.
		13·6	Te.	n.
		14·1	Mi.	n.
		15·4	Di.	n.
	25	3·1	Rh.	s.
		12·3	Te.	s.
		12·7	Mi.	n.
		16·9	En.	s.
	26	0·3	Di.	s.
		9·3	En.	n.
		10·9	Te.	n.
		11·3	Mi.	n.
	27	9·1	Di.	n.
		9·3	Rh.	n.
		9·6	Te.	s.
		9·9	Mi.	n.
		18·2	En.	n.
	28	8·2	Te.	n.
		10·7	En.	s.
		17·9	Di.	s.
		19·9	Mi.	s.
	29	6·9	Te.	s.
		15·5	Rh.	s.
		18·5	Mi.	s.
		19·5	En.	s.
	30	2·8	Di.	n.
		5·5	Te.	n.
		12·0	En.	n.
		17·1	Mi.	s.
Oct.	1	4·2	Te.	s.
		11·6	Di.	s.
		15·7	Mi.	s.
		20·9	En.	n.
		21·7	Rh.	n.
	2	2·8	Te.	n.

1883.		h		
Oct.	2	13·3	En.	s.
		14·3	Mi.	s.
		20·4	Di.	n.
	3	1·5	Te.	s.
		12·9	Mi.	s.
		22·2	En.	s.
	4	0·1	Te.	n.
		3·9	Rh.	s.
		5·3	Di.	s.
		11·6	Mi.	s.
		14·6	En.	n.
		22·8	Te.	s.
	5	7·1	En.	s.
		10·2	Mi.	s.
		14·1	Di.	n.
		21·4	Te.	n.
	6	10·0	Rh.	n.
		15·9	En.	n.
		20·1	Te.	s.
		20·1	Mi.	n.
		23·0	Di.	s.
	7	8·4	En.	n.
		18·7	Te.	n.
		18·7	Mi.	n.
	8	7·8	Di.	n.
		16·2	Rh.	s.
		17·2	En.	n.
		17·3	Mi.	n.
		17·4	Te.	s.
	9	9·7	En.	s.
		15·9	Mi.	n.
		16·0	Te.	n.
		16·6	Di.	s.
	10	14·6	Mi.	n.
		14·7	Te.	s.
		18·6	En.	s.
		22·4	Rh.	n.
	11	1·5	Di.	n.
		11·0	En.	n.
		13·2	Mi.	n.

1883.		h		
Oct.	11	13·3	Te.	n.
	12	10·3	Di.	s.
		11·8	Mi.	n.
		12·0	Te.	s.
		19·9	En.	n.
	13	4·6	Rh.	s.
		10·4	Mi.	n.
		10·6	Te.	n.
		12·3	En.	s.
		19·1	Di.	n.
	14	9·0	Mi.	n.
		9·3	Te.	s.
		20·3	Mi.	s.
		21·2	En.	s.
	15	3·9	Di.	s.
		7·9	Te.	n.
		10·8	Rh.	n.
		13·6	En.	n.
		18·9	Mi.	s.
	16	6·5	Te.	s.
		12·8	Di.	n.
		17·5	Mi.	s.
		22·5	En.	n.
	17	5·2	Te.	n.
		16·9	Rh.	s.
		21·6	Di.	s.
	18	3·8	Te.	s.
	19	2·5	Te.	n.
		6·4	Di.	n.
		23·1	Rh.	n.
	20	1·1	Te.	s.
		8·7	En.	s.
		12·0	Mi.	s.
		15·3	Di.	s.
		23·8	Te.	n.
	21	10·6	Mi.	s.
		17·6	En.	s.
		22·4	Te.	s.
	22	0·1	Di.	n.
		5·3	Rh.	s.

1883.		h		
Oct.	22	9·2	Mi.	s.
		10·0	En.	n.
		21·1	Te.	n.
	23	8·9	Di.	s.
		18·9	En.	n.
		19·2	Mi.	n.
		19·7	Te.	s.
	24	11·3	En.	s.
		11·4	Rh.	n.
		17·7	Di.	n.
		17·8	Mi.	n.
		18·4	Te.	n.
	25	16·4	Mi.	n.
		17·0	Te.	s.
		20·2	En.	s.
	26	2·6	Di.	s.
		12·6	En.	n.
		15·0	Mi.	n.
		15·6	Te.	n.
		17·6	Rh.	s.
	27	11·4	Di.	n.
		13·6	Mi.	n.
		14·3	Te.	s.
		21·5	En.	n.
	28	12·2	Mi.	n.
		12·9	Te.	n.
		14·0	En.	s.
		20·2	Di.	s.
		23·8	Rh.	n.
	29	6·4	En.	n.
		10·8	Mi.	n.
		11·6	Te.	s.
	30	5·0	Di.	n.
		9·4	Mi.	n.
		10·2	Te.	n.
		15·3	En.	n.
	31	5·9	Rh.	s.
		7·7	En.	s.
		8·9	Te.	s.
		13·9	Di.	s.

1883.		h		
Oct.	31	19·4	Mi.	s.
Nov.	1	7·5	Te.	n.
		16·6	En.	s.
		18·0	Mi.	s.
		22·7	Di.	n.
	2	6·2	Te.	s.
		9·0	En.	n.
		12·1	Rh.	n.
		16·6	Mi.	s.
	3	4·8	Te.	n.
		7·5	Di.	s.
		15·2	Mi.	s.
		17·9	En.	n.
	4	3·4	Te.	s.
		10·3	En.	s.
		13·8	Mi.	s.
		16·3	Di.	n.
		18·2	Rh.	s.
	5	2·1	Te.	n.
		12·4	Mi.	s.
		19·2	En.	s.
	6	0·7	Te.	s.
		1·1	Di.	s.
		11·0	Mi.	s.
		11·6	En.	n.
		23·4	Te.	n.
	7	0·4	Rh.	n.
		9·7	Mi.	s.
		10·0	Di.	n.
		20·5	En.	n.
		21·0	Mi.	n.
		22·0	Te.	s.
	8	8·3	Mi.	s.
		13·0	En.	s.
		18·9	Di.	s.
		19·6	Mi.	n.
		20·7	Te.	n.
	9	5·4	En.	n.
		6·5	Rh.	s.
		18·2	Mi.	n.
Nov.	9	19·3	Te.	s.
		21·8	En.	s.
	10	3·6	Di.	n.
		14·3	En.	n.
		16·8	Mi.	n.
		17·9	Te.	n.
	11	6·7	En.	s.
		12·4	Di.	s.
		12·7	Rh.	n.
		15·4	Mi.	n.
		16·6	Te.	s.
	12	14·0	Mi.	n.
		15·2	Te.	n.
		15·6	En.	s.
		21·3	Di.	n.
	13	8·0	En.	n.
		12·6	Mi.	n.
		13·9	Te.	s.
		18·8	Rh.	s.
	14	6·1	Di.	s.
		12·5	Te.	n.
	15	11·2	Te.	s.
		14·9	Di.	n.
	16	1·0	Rh.	n.
		9·8	Te.	n
		17·2	En.	s
		23·7	Di.	s.
	17	7·1	Mi.	n.
		8·4	Te.	s.
		10·6	En.	n.
		18·4	Mi.	s.
	18	3·1	En.	s.
		7·1	Te.	n.
		7·2	Rh.	s.
		8·5	Di.	n.
		17·0	Mi.	s.
		19·5	En.	n.
	19	5·7	Te.	s.
		11·9	En.	s.
		15·6	Mi.	s.
Nov.	19	17·4	Di.	s.
	20	4·4	Te.	n.
		4·4	En.	n.
		13·3	Rh.	n.
		14·2	Mi.	s.
		20·8	En.	s.
	21	2·2	Di.	n.
		3·0	Te.	s.
		12·8	Mi.	s.
		13·3	En.	n.
	22	1·7	Te.	n.
		5·7	En.	s.
		11·0	Di.	s.
		11·5	Mi.	s.
		19·5	Rh.	s.
		22·1	En.	n.
	23	0·3	Te.	s.
		10·1	Mi.	s.
		14·6	En.	s.
		19·8	Di.	n.
		22·9	Te.	n.
	24	7·0	En.	n.
		8·7	Mi.	s.
		21·6	Te.	s.
	25	1·6	Rh.	n.
		4·6	Di.	s.
		7·3	Mi.	s.
		15·9	En.	n.
		18·6	Mi.	n.
		20·2	Te.	n.
	26	8·3	En.	s.
		13·5	Di.	n.
		17·2	Mi.	n.
		18·9	Te.	s.
	27	7·8	Rh.	s.
		15·8	Mi.	n.
		17·2	En.	s.
		17·5	Te.	n.
		22·3	Di.	s.
	28	9·6	En.	n.

1883.	h		
Nov. 28	14·4	Mi.	n.
	16·2	Te.	s.
29	7·1	Di.	n.
	13·1	Mi.	n.
	13·9	Rh.	n.
	14·8	Te.	n.
	18·5	En.	n.
30	10·9	En.	s.
	11·7	Mi.	n.
	13·4	Te.	s.
	15·9	Di.	s.
Dec. 1	3·4	En.	n.
	10·3	Mi.	n.
	12·1	Te.	n.
	19·8	En.	s.
	20·1	Rh.	s.
2	0·7	Di.	n.
	8·9	Mi.	n.
	10·7	Te.	s.
	12·2	En.	n.
3	4·7	En.	s.
	7·5	Mi.	n.
	9·4	Te.	n.
	9·6	Di.	s.
	18·8	Mi.	s.
	21·1	En.	n.
4	2·2	Rh.	n.
	6·1	Mi.	n.
	8·0	Te.	s.
	13·6	En.	s.
	18·4	Di.	n.
5	6·0	En.	n.
	6·7	Te.	n.
	16·0	Mi.	s.
	22·4	En.	s.
6	3·2	Di.	s.
	5·3	Te.	s.
	8·4	Rh.	s.
	14·7	Mi.	s.
	14·9	En.	n.

1883.	h		
Dec. 7	3·9	Te.	n.
	7·3	En.	s.
	12·0	Di.	n.
	13·3	Mi.	s.
8	2·6	Te.	s.
	11·9	Mi.	s.
	14·5	Rh.	n.
	16·2	En.	s.
	20·9	Di.	s.
9	1·2	Te.	n.
	8·6	En.	n.
	10·5	Mi.	s.
	23·9	Te.	s.
10	5·7	Di.	n.
	9·1	Mi.	s.
	17·5	En.	n.
	20·7	Rh.	s.
	22·5	Te.	n.
11	14·5	Di.	s.
	21·2	Te.	s.
12	19·8	Te.	n.
	23·3	Di.	n.
13	2·8	Rh.	n.
	18·5	Te.	s.
14	8·1	Di.	s.
	14·9	Mi.	n.
	17·1	Te.	n.
	20·1	En.	n.
15	9·0	Rh.	s.
	12·6	En.	s.
	13·5	Mi.	n.
	15·7	Te.	s.
	17·0	Di.	n.
16	5·0	En.	n.
	12·1	Mi.	n.
	14·4	Te.	n.
	21·4	En.	s.
17	1·8	Di.	s.
	10·7	Mi.	n.
	13·0	Te.	s.

1883.	h		
Dec. 17	13·9	En.	n.
	15·1	Rh.	n.
18	6·3	En.	s.
	9·3	Mi.	n.
	10·6	Di.	n.
	11·7	Te.	n.
19	7·9	Mi.	n.
	10·3	Te.	s.
	15·2	En.	s.
	19·4	Di.	s.
	21·3	Rh.	s.
20	6·6	Mi.	n.
	7·6	En.	n.
	9·0	Te.	n.
21	0·1	En.	s.
	4·3	Di.	n.
	5·2	Mi.	n.
	7·6	Te.	s.
	16·5	Mi.	s.
	16·5	En.	n.
22	3·4	Rh.	n.
	3·8	Mi.	n.
	6·3	Te.	n.
	8·9	En.	s.
	13·1	Di.	s.
	15·1	Mi.	s.
23	1·4	En.	n.
	4·9	Te.	s.
	13·7	Mi.	s.
	17·8	En.	s.
	21·9	Di.	n.
24	3·5	Te.	n.
	9·6	Rh.	s.
	10·3	En.	n.
	12·3	Mi.	s.
25	2·2	Te.	s.
	2·7	En.	s.
	6·7	Di.	s.
	10·9	Mi.	s.
26	0·8	Te.	n.

		h		
1883. Dec.	26	9·6	Mi.	s.
		11·6	En.	s.
		15·6	Di.	n.
		15·8	Rh.	n.
		23·5	Te.	s.
	27	4·0	En.	n.
		8·2	Mi.	s.
		22·1	Te.	n.
	28	0·4	Di.	s.
		6·8	Mi.	s.
		12·9	En.	n.
		20·8	Te.	s.
		21·9	Rh.	s.
	29	5·3	En.	s.
		5·4	Mi.	s.
		9·2	Di.	n.
		16·7	Mi.	n.
		19·4	Te.	n.
	30	4·0	Mi.	s.
		14·2	En.	s.
		15·3	Mi.	n.
		18·1	Di.	s.
		18·1	Te.	s.
	31	4·1	Rh.	n.
		6·6	En.	n.
		13·9	Mi.	n.
1884.		16·7	Te.	n.
Jan.	1	2·9	Di.	n.
		12·6	Mi.	n.
		15·4	Te.	s.
		15·5	En.	n.
	2	8·0	En.	s.
		10·3	Rh.	s.
		11·2	Mi.	n.
		11·7	Di.	s.
		14·0	Te.	n.
	3	0·4	En.	n.
		9·8	Mi.	n.
		12·7	Te.	s.
		16·8	En.	s.

		h		
1884. Jan.	3	20·5	Di.	n.
	4	8·4	Mi.	n.
		9·3	En.	n.
		11·3	Te.	n.
		16·4	Rh.	n.
	5	1·7	En.	s.
		5·4	Di.	s.
		7·0	Mi.	n.
		10·0	Te.	s.
	6	5·6	Mi.	n.
		8·6	Te.	n.
		10·6	En.	s.
		14·2	Di.	n.
		22·6	Rh.	s.
	7	3·0	En.	n.
		4·3	Mi.	n.
		7·3	Te.	s.
		23·0	Di.	s.
	8	5·9	Te.	n.
		11·9	En.	n.
	9	4·4	En.	s.
		4·6	Te.	s.
		4·8	Rh.	n.
		7·9	Di.	n.
	10	3·2	Te.	n.
		11·4	Mi.	s.
		13·2	En.	s.
		16·7	Di.	s.
	11	1·9	Te.	s.
		5·7	En.	n.
		10·0	Mi.	s.
		11·0	Rh.	s.
	12	0·5	Te.	n.
		1·5	Di.	n.
		8·6	Mi.	s.
		14·6	En.	n.
		23·2	Te.	s.
	13	7·0	En.	s.
		7·3	Mi.	s.
		10·4	Di.	s.

		h		
1884. Jan.	13	17·2	Rh.	n.
		21·8	Te.	n.
	14	5·9	Mi.	s.
		15·9	En.	s.
		19·2	Di.	n.
		20·5	Te.	s.
	15	4·5	Mi.	s.
		8·3	En.	n.
		15·8	Mi.	n.
		19·1	Te.	n.
		23·3	Rh.	s.
	16	0·8	En.	s.
		3·1	Mi.	s.
		4·0	Di.	s.
		14·4	Mi.	n.
		17·8	Te.	s.
	17	9·7	En.	s.
		12·9	Di.	n.
		13·0	Mi.	n.
		16·4	Te.	n.
	18	2·1	En.	n.
		5·5	Rh.	n.
		11·7	Mi.	n.
		15·1	Te.	s.
		21·7	Di.	s.
	19	10·3	Mi.	n.
		11·0	En.	n.
		13·7	Te.	n.
	20	3·4	En.	s.
		6·6	Di.	n.
		8·9	Mi.	n.
		11·7	Rh.	s.
		12·4	Te.	s.
	21	7·5	Mi.	n.
		11·0	Te.	n.
		12·3	En.	s.
		15·4	Di.	s.
	22	4·8	En.	n.
		6·1	Mi.	n.
		9·7	Te.	s.

1884.		h		
Jan.	22	17·9	Rh.	n.
	23	0·2	Di.	n.
		4·8	Mi.	n.
		8·3	Te.	n.
		13·6	En.	n.
	24	3·4	Mi.	n.
		6·1	En.	s.
		7·0	Te.	s.
		9·1	Di.	s.
		14·7	Mi.	s.
	25	0·1	Rh.	s.
		5·6	Te.	n.
		13·3	Mi.	s.
		15·0	En.	s.
		17·9	Di.	n.
	26	4·3	Te.	s.
		7·4	En.	n.
		11·9	Mi.	s.
	27	2·8	Di.	s.
		2·9	Te.	n.
		6·3	Rh.	n.
		10·5	Mi.	s.
	28	1·6	Te.	s.
		8·7	En.	s.
		9·2	Mi.	s.
		11·6	Di.	n.
	29	0·2	Te.	n.
		1·2	En.	n.
		7·8	Mi.	s.
		12·5	Rh.	s.
		20·4	Di.	s.
		22·9	Te.	s.
	30	6·4	Mi.	s.
		10·1	En.	n.
		21·6	Te.	n.
	31	2·5	En.	s.
		5·0	Mi.	s.
		5·3	Di.	n.
		18·7	Rh.	n.
		20·2	Te.	s.

1884.		h		
Feb.	1	3·6	Mi.	s.
		11·4	En.	s.
		14·1	Di.	s.
		14·9	Mi.	n.
		18·9	Te.	n.
	2	2·3	Mi.	s.
		3·8	En.	n.
		13·6	Mi.	n.
		17·5	Te.	s.
		23·0	Di.	n.
	3	0·9	Rh.	s.
		12·2	Mi.	n.
		12·7	En.	n.
		16·2	Te.	n.
	4	7·8	Di.	s.
		14·8	Te.	s.
	5	7·2	Rh.	n.
		13·5	Te.	n.
		16·7	Di.	n.
	6	12·1	Te.	s.
	7	1·5	Di.	s.
		6·7	Mi.	n.
		10·8	Te.	n.
		13·4	Rh.	s.
		15·4	En.	n.
	8	5·3	Mi.	n.
		7·8	En.	s.
		9·5	Te.	s.
		10·4	Di.	n.
	9	3·9	Mi.	n.
		8·1	Te.	n.
		16·7	En.	s.
		19·2	Di.	s.
		19·6	Rh.	n.
	10	6·8	Te.	s.
		9·2	En.	n.
		13·8	Mi.	s.
	11	1·6	En.	s.
		4·1	Di.	n.
		5·4	Te.	n.

1884.		h		
Feb.	11	12·5	Mi.	s.
	12	1·8	Rh.	s.
		4·1	Te.	s.
		10·5	En.	s.
		11·1	Mi.	s.
		12·9	Di.	s.
	13	2·7	Te.	n.
		3·0	En.	n.
		9·7	Mi.	s.
		21·8	Di.	n.
	14	1·4	Te.	s.
		8·1	Rh.	n.
		8·3	Mi.	s.
		11·9	En.	n.
	15	0·1	Te.	n.
		4·3	En.	s.
		6·6	Di.	s.
		7·0	Mi.	s.
		22·7	Te.	s.
	16	5·6	Mi.	s.
		13·2	En.	s.
		14·3	Rh.	s.
		15·5	Di.	n.
		21·4	Te.	n.
	17	4·2	Mi.	s.
		5·6	En.	n.
		20·0	Te.	s.
	18	0·3	Di.	s.
		14·1	Mi.	n.
		14·5	En.	n.
		18·7	Te.	n.
		20·5	Rh.	n.
	19	7·0	En.	s.
		9·2	Di.	n.
		12·8	Mi.	n.
		17·4	Te.	s.
	20	11·4	Mi.	n.
		15·9	En.	s.
		16·0	Te.	n.
		18·0	Di.	s.

Greenwich, Noon.		Titan. $\alpha_s - A$	Titan. $\delta_s - D$	Iapetus. $\alpha_s - A$	Iapetus. $\delta_s - D$
		s	"	s	"
1883, Sept.	5	−13·05	− 5·0	−27·70	−186·5
	6	−12·55	−36·2	−25·68	−189·2
	7	−10·11	−62·1	−23·49	−190·6
	8	− 6·13	−78·6	−21·13	−190·8
	9	− 1·25	−83·8	−18·62	−189·7
	10	+ 3·84	−77·0	−15·98	−187·3
	11	+ 8·40	−59·4	−13·22	−183·7
	12	+11·79	−33·3	−10·36	−178·9
	13	+13·50	− 2·4	− 7·43	−172·9
	14	+13·25	+29·0	− 4·43	−165·7
	15	+10·99	+56·1	− 1·40	−157·5
	16	+ 7·01	+74·5	+ 1·66	−148·2
	17	+ 1·88	+80·9	+ 4·72	−138·0
	18	− 3·57	+74·0	+ 7·76	−126·8
	19	− 8·44	+54·7	+10·77	−114·8
	20	−11·93	+26·2	+13·72	−102·0
	21	−13·46	− 7·0	+16·60	− 88·6
	22	−12·85	−38·7	+19·38	− 74·5
	23	−10·25	−64·9	+22·06	− 60·0
	24	− 6·09	−81·4	+24·62	− 45·0
	25	− 1·03	−86·1	+27·04	− 29·7
	26	+ 4·20	−78·5	+29·30	− 14·1
	27	+ 8·86	−59·8	+31·39	+ 1·6
	28	+12·27	−32·6	+33·31	+ 17·3
	29	+13·93	− 0·6	+35·03	+ 33·0
	30	+13·55	+31·5	+36·55	+ 48·6
Oct.	1	+11·11	+59·0	+37·86	+ 63·9
	2	+ 6·92	+77·3	+38·96	+ 79·0
	3	+ 1·60	+83·1	+39·83	+ 93·6
	4	− 4·00	+75·1	+40·47	+107·7
	5	− 8·95	+54·6	+40·87	+121·3
	6	−12·42	+24·9	+41·03	+134·2
	7	−13·86	− 9·1	+40·96	+146·4
	8	−13·08	−41·7	+40·64	+157·7
	9	−10·28	−68·0	+40·09	+168·2
	10	− 5·91	−84·1	+39·30	+177·7
	11	− 0·67	−88·1	+38·27	+186·2
	12	+ 4·69	−79·4	+37·02	+193·7
	13	+ 9·40	−59·5	+35·54	+200·0

may get information about the places of the satellites at a glance. The places change in the direction of *de*creasing position-angles.

τ	*Mimas.*		*Enceladus.*		*Tethys.*		*Dione.*		*Rhea.*	
h	x	y	x	y	x	y	x	y	x	y
0	0·0	1·4	0·0	1·7	0·0	2·2	0·0	2·8	0·0	3·9
1	0·9	1·3	0·8	1·7	0·7	2·1	0·6	2·8	0·5	3·9
2	1·7	1·1	1·5	1·6	1·4	2·1	1·2	2·7	1·0	3·8
3	2·3	0·9	2·2	1·4	2·0	2·0	1·8	2·7	1·5	3·8
4	2·8	0·6	2·8	1·3	2·6	1·8	2·4	2·6	2·0	3·7
5	3·1	0·3	3·3	1·0	3·2	1·6	2·9	2·5	2·5	3·7
6	3·1	0·1	3·7	0·7	3·7	1·4	3·5	2·3	3·0	3·6
7	2·9	0·5	3·9	0·4	4·1	1·2	4·0	2·2	3·5	3·6
8	2·5	0·8	4·0	0·1	4·5	0·9	4·4	2·0	4·0	3·5
9					4·7	0·7	4·8	1·8	4·5	3·4
10					4·9	0·4	5·2	1·6	4·9	3·2
11					5·0	0·1	5·6	1·4	5·3	3·1
12							5·8	1·1	5·7	3·0
13							6·1	0·9	6·1	2·8
14							6·2	0·6	6·5	2·7
15							6·3	0·4	6·8	2·5
16							6·4	0·1	7·1	2·3
18									7·7	1·9
20									8·2	1·5
27									8·9	0·3

The following ephemerides of *Titan* and *Iapetus* give the positions of the two satellites in reference to the circle of declination.

Differences of Right Ascension and Declination between the Satellites Titan and Iapetus, and the Centre of Saturn.

	Titan.		*Iapetus.*	
Greenwich, Noon.	$\alpha_s - A$	$\delta_s - D$	$\alpha_s - A$	$\delta_s - D$
	s	″	s	″
1883, Aug. 27	+11·38	−33·3	−36·03	−111·7
28	+13·09	− 3·4	−36·05	−123·9
29	+12·91	+27·0	−35·82	−135·2
30	+10·78	+53·6	−35·35	−145·7
31	+ 6·97	+71·8	−34·65	−155·2
Sept. 1	+ 2·03	+78·6	−33·71	−163·7
2	− 3·25	+72·5	−32·53	−171·1
3	− 8·02	+54·2	−31·13	−177·4
4	−11·47	+26·9	−29·52	−182·6

Greenwich, Noon.	Titan. $\alpha_s - A$	Titan. $\delta_s - D$	Iapetus. $\alpha_s - A$	Iapetus. $\delta_s - D$
	s	"	s	"
1883, Nov. 22	−10·61	+49·2	−32·12	−206·1
23	−13·66	+16·4	−29·94	−210·0
24	−14·47	−19·0	−27·54	−212·3
25	−12·95	−51·5	−24·94	−213·2
26	− 9·44	−76·0	−22·17	−212·6
27	− 4·50	−89·1	−19·24	−210·5
28	+ 1·09	−89·3	−16·18	−207·0
29	+ 6·53	−76·7	−13·01	−202·0
30	+11·05	−53·2	− 9·75	−195·6
Dec. 1	+13·98	−22·2	− 6·42	−187·9
2	+14·89	+12·0	− 3·05	−178·9
3	+13·57	+44·3	+ 0·34	−168·7
4	+10·19	+69·8	+ 3·73	−157·2
5	+ 5·18	+84·2	+ 7·09	−144·7
6	− 0·66	+84·9	+10·40	−131·3
7	− 6·38	+71·3	+13·64	−117·0
8	−11·03	+45·9	+16·79	−102·0
9	−13·83	+12·7	+19·82	− 86·3
10	−14·35	−22·1	+22·72	− 70·1
11	−12·59	−54·0	+25·48	− 53·4
12	− 8·88	−77·3	+28·08	− 36·4
13	− 3·85	−89·0	+30·49	− 19·2
14	+ 1·74	−87·7	+32·71	− 1·8
15	+ 7·08	−73·9	+34·72	+ 15·5
16	+11·40	−49·7	+36·51	+ 32·8
17	+14·09	−18·5	+38·08	+ 49·8
18	+14·74	+15·3	+39·41	+ 66·5
19	+13·19	+46·8	+40·49	+ 82·8
20	+ 9·62	+71·0	+41·33	+ 98·6
21	+ 4·53	+83·8	+41·92	+113·7
22	− 1·28	+83·0	+42·25	+128·2
23	− 6·86	+68·4	+42·33	+141·9
24	−11·29	+42·3	+42·15	+154·7
25	−13·82	+ 9·2	+41·73	+166·6
26	−14·08	−25·3	+41·05	+177·4
27	−12·11	−55·8	+40·13	+187·2
28	− 8·28	−77·6	+38·98	+195·9
29	− 3·21	−87·9	+37·60	+203·4
30	+ 2·31	−85·4	+36·00	+209·6

Greenwich, Noon.	Titan. α_e-A	δ_e-D	Iapetus. α_e-A	δ_e-D
	s	"	s	"
1883, Dec. 31	+7·49	−70·7	+34·19	+214·6
1884, Jan. 1	+11·59	−46·1	+32·18	+218·4
2	+14·04	−15·0	+29·98	+220·8
3	+14·44	+18·1	+27·61	+221·9
4	+12·70	+48·4	+25·08	+221·6
5	+9·02	+71·2	+22·41	+220·1
6	+3·92	+82·7	+19·62	+217·2
7	−1·80	+80·6	+16·73	+213·0
8	−7·21	+65·1	+13·74	+207·6
9	−11·39	+38·8	+10·66	+200·8
10	−13·66	+6·1	+7·51	+192·9
11	−13·70	−27·5	+4·34	+183·8
12	−11·58	−56·7	+1·16	+173·6
13	−7·68	−77·1	−2·01	+162·4
14	−2·65	−86·1	−5·16	+150·1
15	+2·75	−82·6	−8·27	+137·0
16	+7·74	−67·4	−11·32	+123·0
17	+11·62	−42·8	−14·28	+108·3
18	+13·84	−12·1	−17·14	+93·0
19	+14·05	+20·2	−19·88	+77·1
20	+12·18	+49·3	−22·48	+60·7
21	+8·44	+70·8	−24·92	+44·0
22	+3·39	+81·0	−27·19	+27·1
23	−2·20	+77·9	−29·27	+10·0
24	−7·40	+62·0	−31·15	−7·1
25	−11·34	+35·7	−32·82	−24·0
26	−13·40	+3·6	−34·25	−40·8
27	−13·27	−29·0	−35·46	−57·2
28	−11·05	−56·9	−36·41	−73·1
29	−7·15	−76·1	−37·11	−88·5
30	−2·21	−84·0	−37·57	−103·3
31	+3·03	−79·8	−37·76	−117·3
Feb. 1	+7·83	−64·4	−37·70	−130·5
2	+11·51	−39·9	−37·37	−142·7
3	+13·51	−9·8	−36·79	−153·9
4	+13·62	+21·5	−35·96	−164·0
5	+11·67	+49·5	−34·89	−172·9
6	+7·95	+69·9	−33·59	−180·6

Greenwich, Noon.	Titan. $\alpha_s - A$	Titan. $\delta_s - D$	Iapetus. $\alpha_s - A$	Iapetus. $\delta_s - D$
	s	"	s	"
1884, Feb. 7	+ 2·98	+ 79·1	−32·06	−187·1
8	− 2·45	+ 75·4	−30·32	−192·2
9	− 7·45	+ 59·2	−28·37	−196·1
10	−11·19	+ 33·2	−26·24	−198·6
11	−13·07	+ 1·8	−23·95	−199·7
12	−12·83	−29·8	−21·50	−199·5
13	−10·58	−56·7	−18·92	−198·0
14	− 6·73	−74·9	−16·22	−195·2
15	− 1·95	−82·0	−13·42	−191·1
16	+ 3·18	−77·3	−10·55	−185·7
17	+ 7·80	−61·8	− 7·62	−179·2
18	+11·31	−37·7	− 4·66	−171·5
19	+13·21	− 8·3	− 1·67	−162·8
20	+13·19	+ 22·2	+ 1·31	−153·1
21	+11·22	+ 49·3	+ 4·27	−142·4
22	+ 7·55	+ 68·7	+ 7·19	−130·8
23	+ 2·70	+ 77·2	+10·06	−118·5
24	− 2·69	+ 73·1	+12·85	−105·5
25	− 7·39	+ 56·9	+15·56	− 92·0
26	−10·97	+ 31·3	+18·16	− 77·9
27	−12·73	+ 0·6	+20·63	− 63·4
28	−12·44	−30·1	+22·97	− 48·6
29	−10·20	−56·0	+25·17	− 33·6
Mar. 1	− 6·43	−73·5	+27·21	− 18·4
2	− 1·73	−80·1	+29·09	− 3·2
3	+ 3·21	−75·3	+30·79	+ 12·0
4	+ 7·68	−59·9	+32·30	+ 27·1
5	+11·05	−36·1	+33·62	+ 41·9
6	+12·86	− 7·3	+34·74	+ 56·4
7	+12·80	+ 21·9	+35·66	+ 70·6
8	+10·86	+ 48·7	+36·38	+ 84·3
9	+ 7·26	+ 67·5	+36·89	+ 97·4
10	+ 2·53	+ 75·5	+37·19	+110·0
11	− 2·59	+ 71·3	+37·28	+121·9
12	− 7·26	+ 55·2	+37·17	+133·1
13	−10·72	+ 30·1	+36·84	+143·4
14	−12·41	0·0	+36·32	+153·0
15	−12·10	−30·0	+35·60	+161·6
16	− 9·91	−55·3	+34·68	+169·4

Greenwich, Noon.	Titan. $a_s - A$	Titan. $\delta_s - D$	Iapetus. $a_s - A$	Iapetus. $\delta_s - D$
	s	"	s	"
1884, Mar. 17	− 6·23	−72·2	+33·57	+176·2
18	− 1·66	−78·5	+32·28	+182·0
19	+ 3·14	−73·7	+30·82	+186·7
20	+ 7·49	−58·5	+29·19	+190·4
21	+10·77	−35·2	+27·40	+193·0
22	+12·53	− 6·9	+25·47	+194·6
23	+12·48	+22·2	+23·42	+195·1
24	+10·59	+48·0	+21·26	+194·4

Ephemeris of the Satellite of Neptune, 1883–84. By A. Marth.

P, angle of position of the minor axis of the satellite's apparent orbit, in the direction of superior conjunction.

a, *b*, major and minor semi-axis of the apparent orbit.

$u - U$, longitude of the satellite in its orbit reckoned from the point which is in superior conjunction with the planet, or in opposition to the Earth.

$U + 180°$, planetocentric longitude of the Earth, reckoned in the satellite's orbit from the ascending node on the celestial equator.

B, planetocentric latitude of the Earth above the plane of the orbit.

0h Gr.	P	*a*	*b*	$u-U$	Diff.	U	B
1883.	°	"	"	°	°	°	°
Sept. 6	318·83	16·63	7·31	181·56	612·51	137·95	26·08
16	318·76	16·72	7·34	74·07	·47	138·05	26·05
26	318·66	16·80	7·36	326·54	·42	138·20	25·99
Oct. 6	318·52	16·86	7·37	218·96	·37	138·39	25·91
16	318·36	16·91	7·37	111·33	·33	138·62	25·82
26	318·18	16·95	7·35	3·66	·31	138·87	25·71
Nov. 5	317·98	16·97	7·33	255·97	·29	139·14	25·59
15	317·78	16·97	7·30	148·26	·29	139·42	25·46
25	317·59	16·96	7·26	40·55	·29	139·70	25·33
Dec. 5	317·41	16·92	7·21	292·84	·30	139·96	25·21
15	317·25	16·87	7·16	185·14	·34	140·19	25·10
25	317·11	16·81	7·10	77·48	·37	140·38	25·00
1884.							
Jan. 4	317·00	16·73	7·05	329·85	·41	140·53	24·92
14	316·93	16·65	7·00	222·26	·46	140·63	24·86
24	316·89	16·56	6·95	114·72	·52	140·68	24·83
Feb. 3	316·90	16·46	6·91	7·24	·57	140·67	24·82
13	316·94	16·37	6·88	259·81	·63	140·61	24·84
23	317·02	16·27	6·85	152·44	612·69	140·49	24·88
Mar. 4	317·14	16·19	6·83	45·13		140·31	24·95

If the values of P, a, b and $u-U$ are interpolated for the times for which the apparent places of the satellite are required, the position-angles p and distances s are found by

$$s \sin (P-p) = a \sin (u-U).$$
$$s \cos (P-p) = b \cos (u-U).$$

The satellite moves in the direction of *de*creasing position-angles, and will be at its greatest elongations and at its *sup*erior and *inf*erior conjunctions with the planet at the following hours, Greenwich M.T.:—

nf. elong. $p=P+90^\circ$ $s=a$		*sup.* conj. P b		*sp.* elong. $P-90^\circ$ a		*inf.* conj. $P+180^\circ$ b	
1883.	h		h		h		h
Sept. 7	10·7	Sept. 8	2·9	Sept. 10	9·2	Sept. 11	20·4
13	7·	14	19·0	16	6·2	17	17·5
19	4·8	20	16·0	22	3·3	23	14·6
25	1·8	26	13·1	28	0·4	29	11·7
30	22·9	Oct. 2	10·2	Oct. 3	21·5	Oct. 5	8·7
Oct. 6	20·0	8	7·3	9	18·6	11	5·8
12	17·1	14	4·4	15	15·6	17	2·9
18	14·2	20	1·5	21	12·7	23	0·0
24	11·3	25	22·6	27	9·8	28	21·1
30	8·4	31	19·7	Nov. 2	6·9	Nov. 3	18·2
Nov. 5	5·5	Nov. 6	16·8	8	4·0	9	15·3
11	2·6	12	13·9	14	1·2	15	12·4
16	23·7	18	11·0	19	22·3	21	9·5
22	20·8	24	8·1	25	19·4	27	6·7
28	17·9	30	5·2	Dec. 1	16·5	Dec. 2	3·8
Dec. 4	15·0	Dec. 6	2·3	7	13·6	9	0·9
10	12·2	11	23·4	13	10·7	14	22·0
16	9·3	17	20·5	19	7·8	20	19·1
22	6·4	23	17·6	25	4·9	26	16·2
28	3·4	29	14·7	31	2·0	Jan. 1	13·3
1884. Jan. 3	0·5	Jan. 4	11·8	Jan. 5	23·1	7	10·4
8	21·6	10	8·9	11	20·2	13	7·4
14	18·7	16	6·0	17	17·2	19	4·5
20	15·8	22	3·0	23	14·3	25	1·6
26	12·8	28	0·1	29	11·4	30	22·6
Feb. 1	9·9	Feb. 2	21·2	Feb. 4	8·4	Feb. 5	19·7
7	6·9	8	18·2	10	5·5	11	16·7
13	4·0	14	15·2	16	2·5	17	13·8
19	1·0	20	12·3	21	23·5	23	10·8
24	22·0	26	9·3	27	20·6	29	7·8
Mar. 1	19·1	Mar. 3	6·3	Mar. 4	17·6	Mar. 6	4·8

MONTHLY NOTICES

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Additional Note to Mr. Stone's Paper on the Change in the adopted Length of the "Tabular Mean Solar Day," which takes place with every Change in the adopted value of the Sun's Mean Sidereal Motion.

In the *Comptes Rendus*, No. 3 (July 16, 1883), M. Gaillot has inserted a paper in which he contests the accuracy of my results, with respect to the change of the unit of time with the change of the Sun's mean motion from n' to $n' + \delta n'$, upon two grounds:

(1) A mathematical investigation based upon the assumption that if T be the mean solar day, we can treat T as a function of n and n' considered as independent variables in the equation of condition

$$(n - n' - p + a \cos \omega - u)\,T = 2\pi\,;$$

and

(2) From the small differences which he finds between a direct numerical calculation of the sidereal times at mean noon from Le Verrier's and Bessel's results. This is really a restatement in another form of Sir G. B. Airy's objection. The following is my answer to both these objections: I deny the mathematical legitimacy of M. Gaillot's assumption on page 152, line 10, "Les variables n', n et P sont indépendantes entre elles." I say that such an assumption is erroneous. For n is the "mouvement de rotation de la Terre autour de son axe," and n' is the "moyen mouvement apparent de révolution du Soleil," and they are therefore the numerical representatives of physical facts, and are directly proportional to the adopted unit of time. The ratio, therefore, of $n : n'$ is *constant and independent of the unit of time adopted.* I maintain, therefore, that the condition of constant proportionality between n and n' must be introduced into the equation of condition which fixes the unit of time. If I am right upon this

point M. Gaillot's results are wrong; if M. Gaillot is right in assuming that n, n', and P also, can be treated as independent variables in fixing the length of the unit of time by the equation of condition which he has given, then my results are wrong, and M. Gaillot's deductions are correct.

M. Gaillot's numerical calculations prove nothing whatever with respect to the point at issue; for if LV and B represent the mean sidereal times, according to Le Verrier and Bessel, and

$$\begin{aligned} B &= C + (p + n')t + 2\pi t \\ LV &= C' + (p + n' + \delta n')t' + 2\pi t', \end{aligned}$$

where t and t' are supposed to be expressed in the mean solar days of their respective scales.

Then, if $t = t'$, we have,

$$LV - B = C' - C + \delta n' t,$$

a result which will agree with M. Gaillot's numerical calculations.

But if the unit of time is different in LV on account of the change from n' to $n' + \delta n'$, as I maintain, then,

$$t = t' \left(1 + \frac{\delta n'}{n'}\right),$$

and therefore

$$\begin{aligned} B &= C + (p + n' + \delta n')t' + 2\pi t' + (p + 2\pi)\frac{\delta n'}{n'}.t' \\ LV &= C' + (p + n' + \delta n')t' + 2\pi t' \\ \therefore LV - B &= C' - C - (p + 2\pi)\frac{\delta n'}{n'}.t' \end{aligned}$$

The term $2\pi\frac{\delta n'}{n'}.t'$ is not small, but increases by about $1^{s}\cdot46$ per annum. It is to the neglect of this term on the erroneous assumption that we can have simultaneously $2\pi t$ equal to a multiple of 2π at every mean noon, whether we are using Bessel's or Le Verrier's expression for the sidereal time at mean noon, which has led, in my opinion, to serious errors in our present reckoning of mean solar time.

The question which I have raised is not, therefore, touched by such calculations as those of M. Gaillot, for in them it is *tacitly assumed* that the unit of time is not changed by a change in n', and this is the very point at issue. The question of the reality of the change in the unit of time by the change of n' to $n' + \delta n'$ can only be decided by theory or by a direct reference to the facts of observation. I have, in my opinion, proved the point theoretically, but I have also re-reduced the Lunar observations made at this Observatory and at Greenwich on the assumption of the correctness of my views, and I find that the errors of the Lunar tables from 1864 to 1882 are then very nearly, if not quite, as small as those which existed from 1847 to 1863, and a discussion of the occultations confirms this result.

I might also mention that in the case of the N.P.D.'s, where the tabular quantities are sometimes rapidly increasing and sometimes rapidly decreasing, I find that with our present reckoning of time the tabular N.P.D.'s are systematically larger than the observations whenever the N.P.D. is rapidly increasing, and smaller than the observations whenever the N.P.D. is rapidly decreasing, and that these discrepancies are sensibly removed in my corrected results.

Determinations of Longitude on the East Coast of Africa. By W. H. Finlay, B.A., Chief Assistant, Royal Observatory, Cape of Good Hope.

It was decided in 1880 that a telegraphic determination of the difference of longitude between Aden and the Cape Observatory should be made, and I left the Cape on May 28, 1881, to take part in this operation.

The opportunity seemed an excellent one for determining also the longitudes of the various ports of call on the East Coast, and I determined to avail myself of it, at the suggestion and with the co-operation of the Astronomer Royal at the Cape.

I took with me an 8-inch sextant, by Dollond, an altazimuth by Troughton and Simms (which was also used for determinations of latitude at Durban and Aden), and three chronometers, viz. Parkinson and Bouts 801, Cribb 722 (both mean time), and Dent 1589 (sidereal).

The sidereal chronometer was always used for observing, and was always compared before and after observations with the others, which were kept while on board in my cabin, where the changes of temperature were not considerable.

The altazimuth was one of those used in the Transit of *Venus* Expedition, 1874, and a full description of it will be found on page 18 of the British Observations of the Transit. The values of the divisions of the spirit-levels were determined before I left the Cape, and at every observation the preceding and following divisions of the vertical circle were always read; so that the corrections of runs of the microscope micrometers at any place were always determined from the observations there; this correction, however, was very small. The sextant was in good adjustment. Observations at about the same altitude as those actually made during the Expedition were made before leaving, and showed that no sensible correction was required to the resulting local time for excentricity.

I arrived at Lourenço Marques (Delagoa Bay) on July 2, and by the kindness of the superintendent was allowed to take up my quarters at the station of the Eastern and South African Telegraph Company till the arrival of the British India Company's steamer, which was to take me on to Aden.

The Eastern Company's stations on this coast are Durban, Delagoa Bay, Mozambique, and Zanzibar; and every facility was given me by the superintendents at these places for sending signals through the cable. At Durban there is a short line connecting the Government telegraph office (land line) with the cable office, and there is direct communication between the Government office and the Cape Observatory. On my way to Aden the signals from my end of the cable were noted at Durban and sent on to the Observatory by H. McEwen, Esq., of the Eastern Telegraph Company's staff, and similarly for the signals from the Observatory. Some delay must necessarily occur in such translation, but it will be seen from the results that the delay was very short and constant. On my return to Durban Mr. McEwen and I observed a large number of mirror signals sent from Aden in order to determine our personal equation, and we found that the difference of our estimates of the start of the spot of light was practically insensible, while any error in catching the click of the Morse lever must certainly be small, and quite within the errors of the time determinations. On my return journey Mr. Maclear, of the Cape Observatory, occupied the Durban longitude station, and my signals were exchanged with Durban only. The cable does not touch at Inhambane or Quilimane, so that I had to trust to my chronometers for any determinations at these places; but the interval for which the rate had to be assumed was only a few days.

Table I. gives the average rates of the two mean time chronometers, deduced from cable signals and from comparisons with the Transit Clock at Durban.

These average rates necessarily, in some cases, include the disturbing effects of landing or shipping the chronometers; and I had no material for correcting the rates for change of temperature. They have only, however, been used (1) for the observations at Quilimane, and (2) for deducing the rate of the observing chronometer between the times of observation and of signals at the other places.

TABLE I.

Rates of the Standard Chronometers.

Approximate Cape Mean Time.	Interval.	Cribb.	P. & B.	Remarks.
d h	d	s	s	
July 1 21				
	11·38	+0·11	+1·14	At Delagoa Bay.
13 6				
	15·75	+0·11	+0·84	From Delagoa Bay to Zanzibar.
29 0				
Oct. 4 19				
	12·69	−0·47	+1·14	From Aden to Zanzibar.
17 12				
	6·43	+0·12	+1·66	From Zanzibar to Mozambique.
23 22				
	10·47	+0·28	+1·68	From Mozambique to Delagoa Bay.
Nov. 3 7				
	6·55	+0·61	+1·22	At Delagoa Bay.
9 21				
	6·07	+1·65	+2·09	From Delagoa Bay to Zanzibar.
15 22				

The stay of the British India steamers at Inhambane, Quilimane, and Mozambique, never exceeds twenty-four hours. There are no boats for hire at these places, and we sometimes arrived at night, so that it may be easily understood the time at my disposal was generally short. At Zanzibar the steamer usually stopped two days. I was able to land the altazimuth here each time, and also at Mozambique on the return journey.

I will now give an account of the stations occupied, the observations, and their results.

Delagoa Bay.

July 6–13.—These observations were altitudes of the Sun with the sextant and artificial horizon at the flag-staff of the E.S.A.T.C. This is a well-marked position on the top of the hill at Punta Vermelha (Reuben Point).

Latitude.

Date.	No. of Observations.	Observed.	Adopted.
		° ′ ″	° ′ ″
July 6	8	−25 58 4	
7	6	−25 58 11	−25 58 4
13	12	−25 57 55	

For time the chronometer error is given from the mean of morning and afternoon determinations.

Time.

Date.	Dent slow on local sidereal time.
d h	h m s
July 7 0	1 6 49·1
11 0	1 6 58·8
12 0	1 7 2·5
13 0	1 7 7·6
13 12	1 7 9·0

Signals were exchanged with the Observatory on the night of July 13, with hand-translation at Durban. These give for the difference of longitude

	h m s
From Cape Signals	0 56 28·6
,, Delagoa Bay Signals	27·2
Mean	0 56 27·9

And the "retardation" or "loss of time" = $0^s.7$.

I left Delagoa Bay on July 15.

November.—On my return journey constant rain and cloudy weather prevented any observations until the day before I left. On November 9, at 18^h mean time, I exchanged signals with Mr.

Maclear at Durban, and secured observations of the Sun with the sextant directly afterwards. These give for the difference of longitude between Durban and Delagoa Bay

	h	m	s
From Durban Signals	0	6	15·37
„ Delagoa Bay Signals			15·01
Mean	0	6	15·2

And retardation = $0^s{\cdot}18$.

No results could be obtained at Inhambane on either visit owing to cloud.

Quilimane.

(*Assumed latitude* $-17^\circ\ 51'\ 44''$.)

July 1.—I landed about 6 A.M., and made observations of the Sun on the steps of the north-east side of the Custom House. The choice of this site was somewhat unfortunate, as shortly after I had commenced numbers of people kept passing in and out for transaction of business, and disturbed the mercury as they passed; but as I had only about an hour at my disposal I did not think it advisable to look out for another well-marked place. We left at $10^h\ 30^m$ A.M.

The errors of the standard chronometers have been deduced from the signals at Zanzibar on July 28 and 29, with the rates in Table I.

At the time of the second comparison of Dent with the standards (i.e. after the observations) these latter differed $0^s{\cdot}86$ in giving Cape mean time: the mean of the two has been adopted. These observations make my station

$$\overset{h}{1}\ \overset{m}{13}\ \overset{s}{33{\cdot}6} \text{ East of the Cape.}$$

The probable error of the local time, obtained from the discordances of the separate observations, is $\pm 0^s{\cdot}3$.

Mozambique.

Arrived Saturday evening, July 23. I landed next morning, and took sextant observations of the Sun in an open space among the trees in front of the Telegraph Office. The flag-staff in Sebastian Fort is 1,027 feet distant, and bears $74^\circ\ 15'$ East of North from this place.*

I exchanged signals with Mr. McEwen at Durban, but failure of the land-line and bad weather for the next three or four days prevented his getting any exchange with the Observatory. I

* For this determination I am indebted to Captain Aldrich, R.N., and the officers of H.M.S. "Fawn."

have therefore deduced the errors of the standard chronometers as at Quilimane. These observations make my station

$$\overset{\text{h}}{1}\ \overset{\text{m}}{29}\ \overset{\text{s}}{5{\cdot}6} \text{ East of the Cape.}$$

The reduction in longitude to the flag-staff is $0^{s}{\cdot}67$.

Owing, however, to the much better determination on the way back, I did not propose to give this result any weight. It happens, however, to agree almost exactly with the later one. I left on Sunday afternoon.

On the return journey, I arrived on Sunday, Oct. 23, about noon. At first the health officer refused us pratique on account of the cholera, which had been prevalent at Aden for some time before I left; but we were allowed to land in the afternoon. The Governor, Vasconde P. d'Arcos, offered me every facility for making my observations in Sebastian Fort, and the observations on this occasion were made with the altazimuth, in the S.E. angle of the Fort, about ten or twelve yards South of the flag-staff.

Latitude.

Star.	Observed.	Adopted.
	° ′ ″	° ′ ″
α Piscis aust.	−15 1 47·3	−15 1 47
α Eridani	46·4	

Time.

The results are corrected for the rate of chronometer Dent, so as to reduce them to a common epoch.

Star.	Chronometer fast	Direction of Star.
	h m s	
θ Scorpii	5 11 25·91	West of Meridian.
α Tauri	26·22	East ,,
α Piscis aust.	25·98	West ,,
β Orionis	26·40	East ,,

Signals could not be got with Durban that night, but were exchanged about 6 A.M. next morning with Mr. McEwen, and the chronometer used by him was shortly afterwards compared with the Durban Transit Clock. The results for the difference of longitude are

	h m s
From Durban Signals	0 38 53·77
,, Mozambique Signals	53·13
Mean	0 38 53·45

And loss of time $= 0^{s}{\cdot}32$.

The horizontal circle of the altazimuth was also read approximately with each of these stars, and for the light on St. George's

Island. According to these observations, which agree well among themselves, the light bears 60° 24′ East of South from my station.

Zanzibar.

Arrived July 28. Dr. (now Sir John) Kirk had built a pillar for the altazimuth on the roof of the Consulate on a solid partition-wall, which ran right through to the ground; but, unfortunately, the pillar was too small to carry the foot-screws. (The late) Captain Brownrigg, H.M.S. "London," most kindly placed the services of his engineers at my disposal, and they cast a brass plate about three-quarters of an inch thick, which was firmly bolted to the pier next morning. The observations on the 28th were made on the top of the altazimuth box; those on the 29th on the pier.

Latitude.

Date.	Star.	Observed.	Adopted.
		° ′ ″	° ′ ″
July 29	α Lyræ	−6 9 48·9	−6 9 51
	α Gruis	53·2	

Time.

Date.	Star.	Chronometer slow.	Direction of Star.
		h m s	
July 28	α Virginis	1 34 1·92	West of Meridian.
	α Scorpii	2·39	West ,,
	α Andromedæ	2·14	East ,,
July 29	α Virginis	1 34 6·54	West ,,
	α Aquarii	6·06	East ,,
	α Scorpii	6·33	West ,,
	γ Pegasi	6·24	East ,,

Signals were exchanged with the Cape Observatory each night, with hand-translation by Mr. McEwen at Durban. The results for difference of longitude are:

		h m s	h m s
July 28	From Cape Signals	1 22 51·18	1 22 50·1
	,, Zanzibar Signals	48·97	
July 29	,, Cape Signals	50·55	1 22 49·5
	,, Zanzibar Signals	48·43	
	Mean ...	... ...	1 22 49·8

And the "loss of time" on the two nights is $1^s·10$ and $1^s·06$ respectively.

Throughout these observations I experienced the greatest kindness and assistance from the members of the E.S.A.T.C., and my thanks are especially due to Messrs. Heraghty, Cassidy, Carlisle, McEwen, and to Sir J. Kirk.

It will be interesting to compare the "retardation," or "loss of time," at the different places. The average loss from Cape Town to Durban was about $0^s{\cdot}2$. We have then:

Cape to Delagoa Bay	$\overset{s}{0}{\cdot}7$	(with hand-translation).
Durban to Delagoa Bay	0·2	
Durban to Mozambique	0·3	
Cape to Zanzibar	1·1	(with hand-translation).

From the first two results it appears that the "loss of time" due to the hand-translation was about $0^s{\cdot}3$; and applying this to the last result, the "loss" on the cable from Durban to Zanzibar would be $0^s{\cdot}6$.

The following table gives the results of my observations. The longitudes used for the Cape Observatory ($1^h\ 13^m\ 54^s{\cdot}7$) and the Durban Hut ($2^h\ 4^m\ 6^s{\cdot}9$) have been taken from Mr. Gill's *Preliminary Account of a Telegraphic Determination of the Longitude of the Royal Observatory, Cape of Good Hope.*

FINAL RESULTS.

Place.	Position of Station.	Date.	Longitude East of Greenwich.	Longitude in Arc.
			h m s	° ′ ″
Delagoa Bay	Flag-staff, E.S.A.T.C.	July 13	2 10 22·6	32 35 35
		Nov. 9	2 10 22·1	
Quilimane	Custom House	July 20	2 27 28·3	36 52 4
Mozambique	Flag-staff, Sebastian Fort	July 23	2 43 0·3	
		Oct. 23	2 43 0·4	40 45 6
Zanzibar	British Consulate	July 28	2 36 44·8	39 11 8
		July 29	2 36 44·2	

Royal Observatory,
Cape of Good Hope:
1883, *May.*

Ephemeris for Physical Observations of Mars, 1883–84.
By A. Marth.

Greenw. Noon. 1883.		P.	Areographical Longit. of Disk's Centre.	Latit. of Disk's Centre.	Diameter.	q	Q	E	Log. Light-ratio.
		°	°	°	″	″	°	°	
Oct.	20	352·47	191·53	+14·75	7·10	0·81	283·53	39·37	9·1286
	22	353·08	172·38	15·06	7·18	·81	283·86	39·36	·1375
	24	353·68	153·24	15·35	7·27	·82	284·17	39·33	·1467
	26	354·27	134·12	15·63	7·36	·83	284·47	39·29	·1561
	28	354·86	115·01	15·90	7·45	·84	284·75	39·23	·1657
	30	355·44	95·91	16·16	7·55	·85	285·02	39·16	·1756
Nov.	1	356·00	76·83	+16·40	7·65	0·85	285·29	39·07	9·1858
	3	356·55	57·77	16·64	7·75	·86	285·54	38·96	·1962
	5	357·09	38·73	16·86	7·85	·87	285·77	38·84	·2069
	7	357·62	19·71	17·07	7·96	·87	285·99	38·70	·2178
	9	358·14	0·70	17·27	8·07	·88	286·20	38·54	·2290
	11	358·64	341·71	17·46	8·18	·88	286·39	38·36	·2405
	13	359·13	322·75	17·64	8·30	·89	286·57	38·17	·2522
	15	359·60	303·81	17·80	8·42	·89	286·73	37·95	·2642
	17	0·06	284·89	17·96	8·55	·89	286·88	37·70	·2765
	19	0·50	266·00	18·10	8·68	·89	287·02	37·43	·2890
	21	0·93	247·13	18·23	8·81	·89	287·14	37·14	·3018
	23	1·34	228·29	18·34	8·95	·89	287·25	36·82	·3149
	25	1·72	209·48	18·45	9·09	·89	287·34	36·48	·3282
	27	2·08	190·70	18·54	9·24	·89	287·41	36·10	·3417
	29	2·43	171·96	18·62	9·39	·88	287·46	35·69	·3555
Dec.	1	2·76	153·25	+18·68	9·54	0·87	287·50	35·25	9·3695
	3	3·06	134·58	18·74	9·70	·87	287·52	34·78	·3838
	5	3·34	115·94	18·78	9·86	·86	287·51	34·27	·3982
	7	3·59	97·34	18·81	10·02	·84	287·49	33·72	·4128
	9	3·82	78·78	18·82	10·19	·83	287·45	33·14	·4275
	11	4·03	60·27	18·83	10·36	·81	287·38	32·52	·4424
	13	4·21	41·80	18·82	10·53	·79	287·29	31·86	·4574
	15	4·35	23·37	18·79	10·71	·77	287·18	31·15	·4725
	17	4·47	4·99	18·76	10·89	·75	287·03	30·40	·4877
	19	4·56	346·66	18·71	11·08	·72	286·86	29·60	·5029
	21	4·62	328·37	18·65	11·26	·69	286·65	28·76	·5180
	23	4·65	310·14	18·57	11·45	·66	286·41	27·87	·5331
	25	4·65	291·96	18·48	11·63	·63	286·13	26·93	·5480

Greenw. Noon. 1883.		P	Areographical Longit. of Disk's Centre	Latit.	Diameter.	q	Q	E	Log. Light-ratio.
Dec.	27	4·61	273·84	18·38	11·82	·60	285·80	25·94	·5628
	29	4·54	255·77	18·27	12·01	·56	285·43	24·90	·5773
	31	4·43	237·75	18·14	12·19	·52	285·00	23·80	·5915
1884. Jan.	2	4·29	219·79	+ 18·00	12·38	0·48	284·51	22·65	9·6054
	4	4·12	201·89	17·84	12·55	·44	283·95	21·46	·6188
	6	3·91	184·03	17·67	12·73	·39	283·30	20·21	·6317
	8	3·67	166·23	17·50	12·89	·35	282·55	18·91	·6439
	10	3·40	148·48	17·31	13·05	·31	281·68	17·57	·6554
	12	3·09	130·78	17·10	13·20	·26	280·65	16·18	·6662
	14	2·75	113·12	16·89	13·34	·22	279·42	14·75	·6762
	16	2·39	95·51	16·67	13·47	·18	277·95	13·28	·6852
	18	2·00	77·94	16·44	13·59	·14	276·11	11·78	·6932
	20	1·59	60·40	16·20	13·69	·11	273·76	10·26	·7001
	22	1·15	42·89	15·95	13·77	·08	270·63	8·73	·7058
	24	0·69	25·41	15·70	13·84	·05	266·23	7·19	·7104
	26	0·21	7·95	15·44	13·89	·03	259·6	5·70	·7137
	28	359·73	350·51	15·19	13·93	·02	248·6	4·30	·7156
	30	359·23	333·07	14·93	13·94	·01	228·8	3·18	·7163
Feb.	1	358·73	315·64	+ 14·68	13·94	0·01	196·5	2·71	9·7155
	3	358·23	298·20	14·43	13·91	·01	164·3	3·19	·7134
	5	357·74	280·76	14·19	13·87	·02	144·8	4·31	·7100
	7	357·25	263·30	13·95	13·81	·03	133·9	5·70	·7053
	9	356·77	245·82	13·73	13·73	·05	127·28	7·17	·6993
	11	356·31	228·31	13·51	13·64	·08	122·88	8·68	·6921
	13	355·86	210·78	13·31	13·53	·11	119·72	10·19	·6837
	15	355·44	193·21	13·13	13·40	·14	117·33	11·68	·6742
	17	355·04	175·59	12·96	13·26	·17	115·45	13·15	·6637
	19	354·67	157·94	12·81	13·12	·21	113·92	14·58	·6522
	21	354·32	140·25	12·67	12·96	·25	112·65	15·97	·6399
	23	354·00	122·51	12·55	12·79	·29	111·57	17·32	·6268
	25	353·71	104·72	12·46	12·61	·33	110·64	18·62	·6129
	27	353·45	86·88	12·38	12·43	·37	109·84	19·87	·5984
	29	353·23	68·99	12·32	12·24	·41	109·14	21·07	·5834
Mar.	2	353·04	51·05	+ 12·28	12·05	0·45	108·53	22·22	9·5679
	4	352·88	33·06	12·27	11·86	·48	108·00	23·32	·5521
	6	352·76	15·01	12·27	11·67	·52	107·54	24·37	·5359
	8	352·67	356·92	12·29	11·47	·55	107·13	25·36	·5195

Greenw. Noon. 1884.	P	Areographical Longit. of Disk's Centre.	Latit. of Disk's Centre.	Diameter.	q	Q	E	Log. Light-ratio.
Mar. 10	352·61	338·77	12·33	11·28	·58	106·77	26·30	·5029
12	352·58	320·58	12·39	11·09	·61	106·47	27·20	·4861
14	352·58	302·34	12·47	10·89	·64	106·21	28·04	·4693
16	352·61	284·05	12·56	10·70	·66	105·99	28·84	·4524
18	352·67	265·72	12·67	10·52	·69	105·80	29·59	·4355
20	352·75	247·35	12·79	10·33	·71	105·65	30·30	·4187
22	352·87	228·93	12·93	10·15	·72	105·53	30·97	·4220
24	353·01	210·47	13·08	9·97	·74	105·44	31·59	·3853
26	353·17	191·97	13·25	9·80	·75	105·38	32·17	·3688
28	353·36	173·43	13·43	9·63	·76	105·34	32·72	·3524
30	353·57	154·86	13·62	9·46	·77	105·32	33·23	·3362
Apr. 1	353·81	136·25	+ 13·82	9·30	0·78	105·33	33·70	9·3202
3	354·07	117·60	14·03	9·14	·79	105·36	34·14	·3044
5	354·35	98·92	14·25	8·99	·79	105·40	34·54	·2888
7	354·65	80·21	14·48	8·84	·80	105·46	34·92	·2735
9	354·96	61·46	14·72	8·69	·80	105·54	35·26	·2584
11	355·30	42·68	14·97	8·55	·80	105·63	35·57	·2436
13	355·65	23·88	15·22	8·41	·80	105·73	35·86	·2291
15	356·02	5·05	15·48	8·28	·79	105·85	36·12	·2148
17	356·41	346·19	15·74	8·15	·79	105·97	36·36	·2007
19	356·81	327·31	16·01	8·02	·79	106·11	36·57	·1869
21	357·23	308·40	16·29	7·90	·78	106·25	36·76	·1734
23	357·66	289·46	16·56	7·78	·78	106·41	36·93	·1601
25	358·11	270·50	16·84	7·67	·78	106·57	37·08	·1471
27	358·57	251·52	17·12	7·56	·77	106·74	37·21	·1344
29	359·04	232·52	17·41	7·45	·76	106·91	37·32	·1220
May 1	359·52	213·50	+ 17·70	7·34	0·76	107·09	37·41	9·1098
3	0·02	194·45	17·99	7·24	·75	107·27	37·48	·0979
5	0·53	175·38	18·27	7·14	·74	107·45	37·54	·0862
7	1·04	156·29	18·56	7·05	·73	107·64	37·58	·0748
9	1·57	137·18	18·85	6·95	·72	107·83	37·61	·0637
11	2·11	118·06	19·14	6·86	·71	108·03	37·62	·0528
13	2·66	98·92	19·42	6·77	·70	108·22	37·62	·0422
15	3·21	79·76	+ 19·71	6·69	0·70	108·42	37·61	9·0318

1883, Oct. 26 ... Spring Equinox of *Mars'* Northern Hemisphere.

1884, May 13 ... Summer Solstice „ „

P denotes the angle of position of the planet's axis, q the amount and Q the position-angle of the greatest defect of illumination, E the areocentric angle between Earth and Sun. The last column gives the logarithm of the ratio of the apparent brightness of *Mars* to that at mean opposition, computed upon the supposition that the diminution of brightness due to the phase depends simply on the proportion of the unilluminated portion to the whole of the disk.

The data of the ephemeris are to be interpolated directly for the times for which they are required, the equation of light having already been taken into account. The difference of successive values of the longitude of the centre of the disk amounts to one rotation and some 340 degrees, so that, for instance, the difference Oct. 20 to 22 is $700^{\circ}{\cdot}85$, and that from Jan. 29 to Feb. 1 $702^{\circ}{\cdot}57$.

The assumed daily rate of rotation is $350^{\circ}{\cdot}8922$. This value, which I have used in my computations since 1864, depended originally on Kaiser's determination of the period of the planet's sidereal rotation $24^{h}\ 37^{m}\ 22^{s}{\cdot}62$, mentioned in his paper, published in April 1864, in No. 1468 of the *Astron. Nachr.* Its approximate correctness, however, has been tested and corroborated quite independently by means of what appear to me by far the best old observations available for the purpose, those made by Maraldi in 1704, and published in the *Mémoires* of the Paris Academy, of 1706. However imperfect representations the sketches there given may be, there seems to be no valid doubt or difficulty in their correct interpretation and in recognising in the spot, the arrival of which at the middle of the disk Maraldi observed on four successive nights, Mädler's r or Schiaparelli's Sinus Titanum. In October 1704 the spot passed the middle line a little to the north of the centre. If observers could have been induced to make corresponding observations in 1877, the circumstances would have been similar and the determination of rotation nearly independent of them; but the opportunity seems to have been missed, and will not come again till 1894, though their best chance observers will not get till 1909. A comparison of the results of Maraldi's observations with those of the corresponding observations of Schiaparelli, made in November 1879, when the spot passed the middle line on the south side of the centre, shows that the adopted rate of rotation is nearly correct, since the means of the deduced areographical longitudes agree within 2°, while an alteration of $0^{\circ}{\cdot}0001$ in the daily rate makes, in the interval from October 1704 to November 1879 a difference of $6^{\circ}{\cdot}3948$. The daily rate $350^{\circ}{\cdot}89217$ of the tropical rotation would give $24^{h}\ 37^{m}\ 22^{s}{\cdot}626$ as the period of the sidereal rotation. For the present I have made no alteration in the adopted rate, nor shifted the zero meridian. The position of the equator of *Mars* is that adopted in the ephemerides for the last two oppositions (v. *Monthly Notices*, vol. xxxix. p. 473). I have

not yet learnt whether the last opposition has yielded any contributions towards a better determination. Perhaps the approaching one may be more fruitful.

Errata.

Page 350, sixth line from bottom. *For* $P_0^{(i)}$ *read* $P_0^{(1)}$.

„ 356, fourth line from top. *For* half *read* twice.

„ 358, coefficient of e^{10} sin 8M. *For* $-\frac{1182827}{2^7.3^4.5.7}$, *read* $-\frac{4745483}{2^9.3^4.5.7}$,

and in the coefficient of e^{12} sin 10M. *For* $-\frac{769805651}{2^{12}.3^4.5.7.11}$, *read* $-\frac{769724 57}{2^{11}.3^4.7.11}$.

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PAGE

LIST OF PRESENTS

RECEIVED DURING THE SESSION OF 1882–83,

AND OF

BOOKS PURCHASED WITH THE TURNOR FUND

DURING THE SAME PERIOD,

FORMING

APPENDIX XXXIV.

To the Catalogue of the Library of the Royal Astronomical Society.

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Airy, Sir G. B., Monthly means of the highest and lowest diurnal temperatures of the water of the Thames, and comparison of the corresponding temperatures of the air at the Royal Observatory, Greenwich, 8vo. *London*, 1882	The Author.
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